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Deformity Correction and Fracture Treatment by software-based Ortho-SUV Frame

User Manual

DRAFT

1. Introduction

In deformity correction of complex multicomponent and multiplanar deformities (http://rniito.org/solomin_eng/deform_class.jpg) by Ilizarov frame, unified reduction nodes have to be replaced three to five times (Fig. 1) (Solomin L.N. et al., 2009). Every frame re-assembly (reductional units change) is quite a laborious process involving additional exposure of patient to radiation. Sometimes - due to particular way the frame is assembled (external supports are not oriented at right angle to the axes of bone fragments, a bone is not at the center of a support, support for some reason is not closed etc.) - correction of one component might lead to secondary translation of other(s). These secondary translations will, in their turn, call for correction and therefore additional frame reassembling.

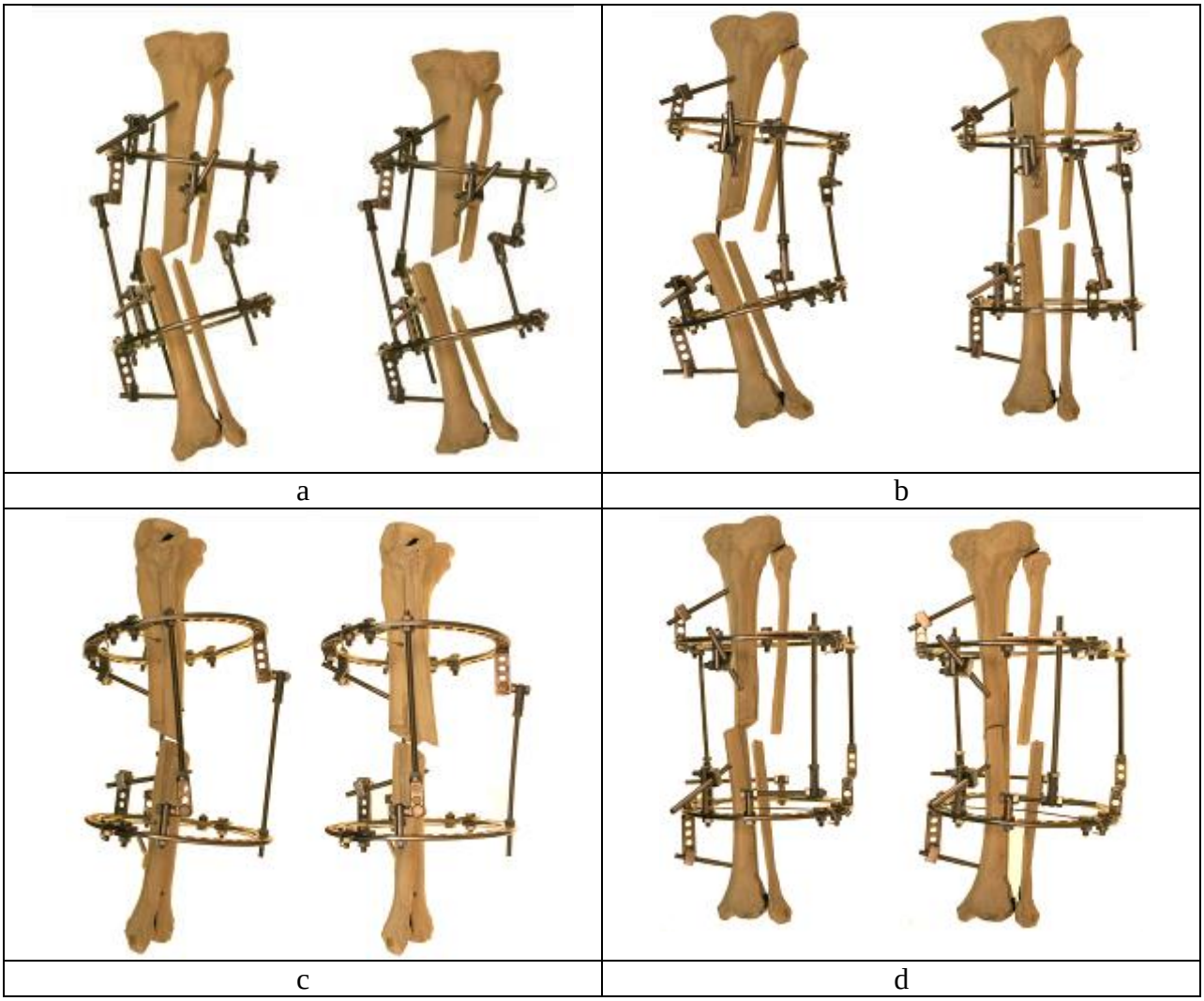
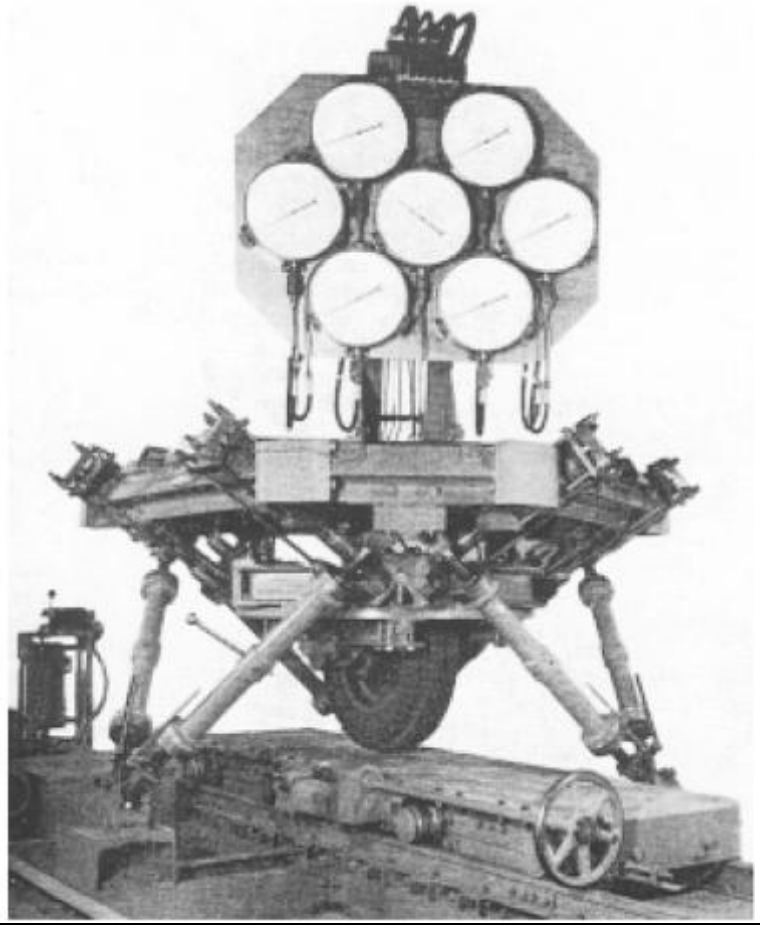


Fig. 1a-d. To correct multicomponented deformity, Ilizarov frame has to be reassembled 3-5 times. a – lengthening; b – correction of slant deformity and frontal plane displacement; c – correction of angular deformity and sagittal plane displacement; d – correction of rotation

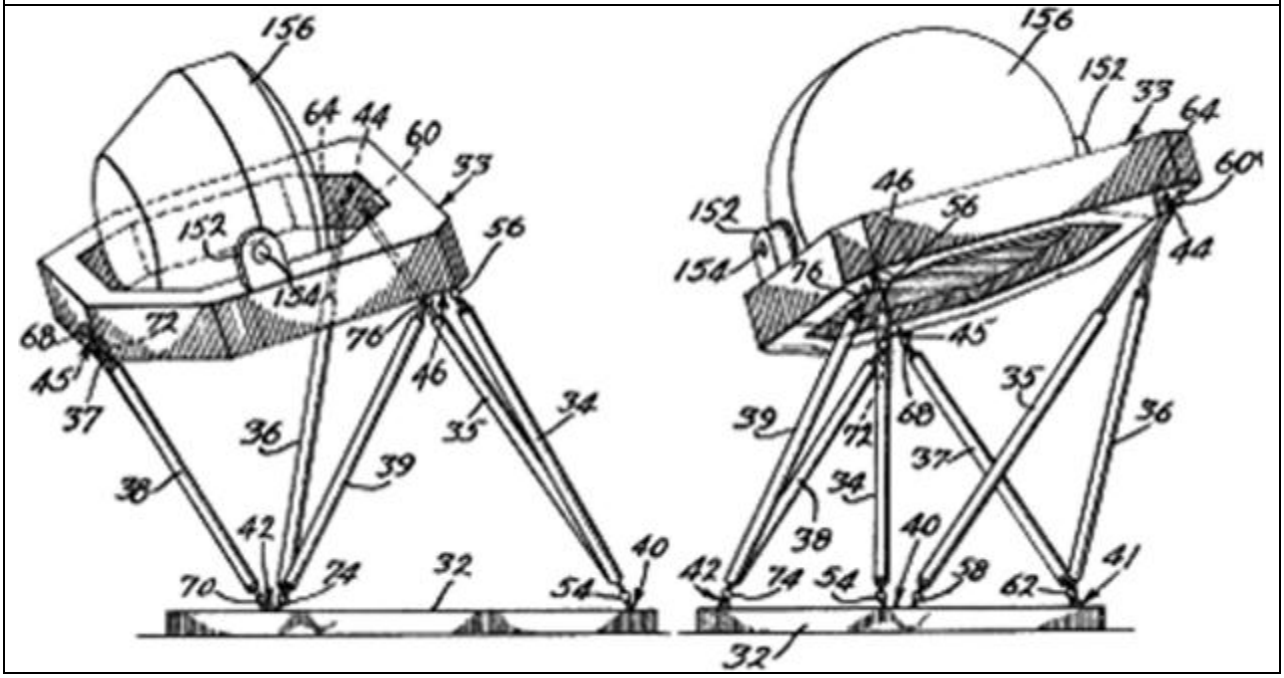
However it is not just in orthopaedy where the issue of controlling an object's position in three-dimensional space is actual. Application of ***hexapods*** is recognized to be a promising trend in this area. Hexapods are appliances structurally consisting of two platforms – one of them being static (basic) and another one mobile. System of *six* telescopic rods (struts) serves to connect these platforms. The ways telescopic rods connect to each other and platforms differ and depend upon an author's

approach (Fig. 2). Quantity of struts does not depend upon how many planes and degrees of freedom platforms have to be moved in relatively to each other. When five struts are used, the system loses its stability, while seven struts make it overstrained.

First hexapod was proposed by Eric Gough in 1947 (Bonev I., 2003) for testing wheels exposed to combined forces (Fig. 2a). Klaus Ceppel in 1962, not having been informed of Gough's invention, created similar mechanism while developing a vibration device (Fig. 2b). D. Stewart in 1965 (Bonev I., 2003) proposed a platform on the basis of original hexapod (Fig. 2c).



a



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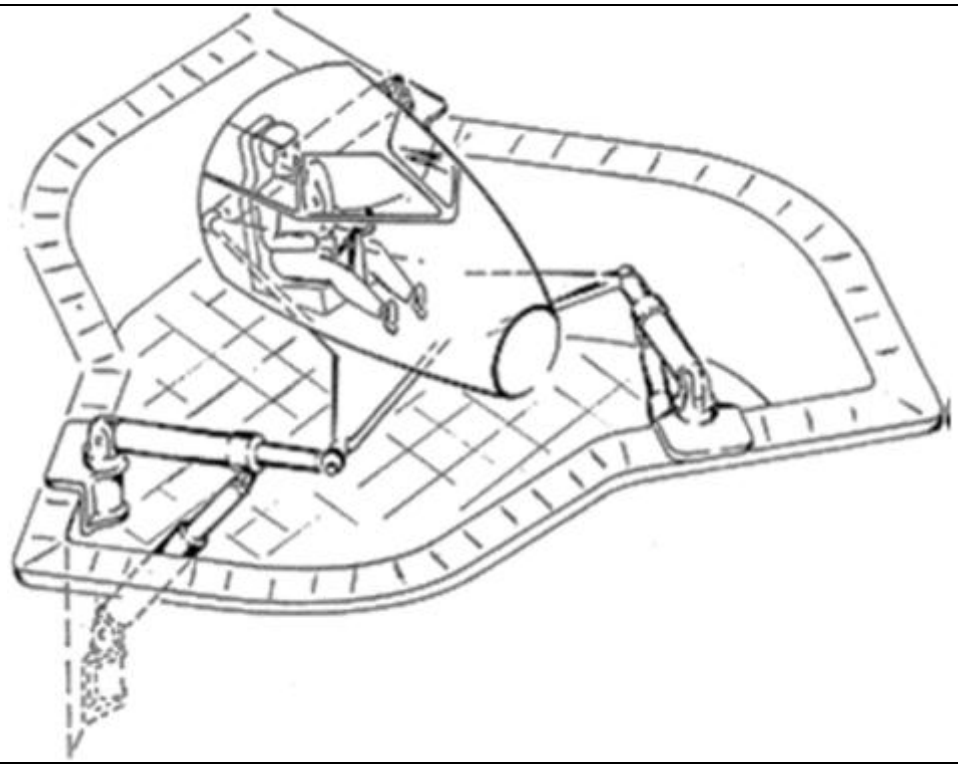


c

Fig. 2a-c. Hexapods. a - E.Gough's sustem; b - K.Ceppel's system; c - D. Stewart's platform (Bonev I., 2003)

Lengthening or shortening of even one strut causes one platform move relative to another in three planes. That's why it takes computer navigation to control these movements.

There are active and passive types of navigation in robotics. As regard to the mechanisms discussed, the *active* navigation implies that computer, after it had been given coordinates of required position of a subject (mobile platform in this case), uses its sensors to automatically obtain all the parameters necessary to achieve the result. When operator confirms his approval, computer manipulates the machinery implementing controlled movement. In *passive* navigation operator provides not only coordinates to be achieved by mobile platform, but also parameters defining its original position, including those ensured by initial strut lengths. Then computer program calculates the necessary length change for all the struts. Only after this stage operator, fine-tuning these lengths, brings mobile platform into its proper position.

With regard to orthopaedics, hexapod may be viewed as *universal reduction node,* a mechanism, which makes it possible to move one platform (one basic support with bone fragment fixed inside) relatively to another by shortest, "integral" trajectory. First "hexapod in orthopaedics" was created at early 90th in Ilizarov Russian Research Center (Fig. 3a) (Shevtsov V.I. et al., 2008, unpublished data). However this device has not been used in clinic, partially due to lack of software.

a	b	c

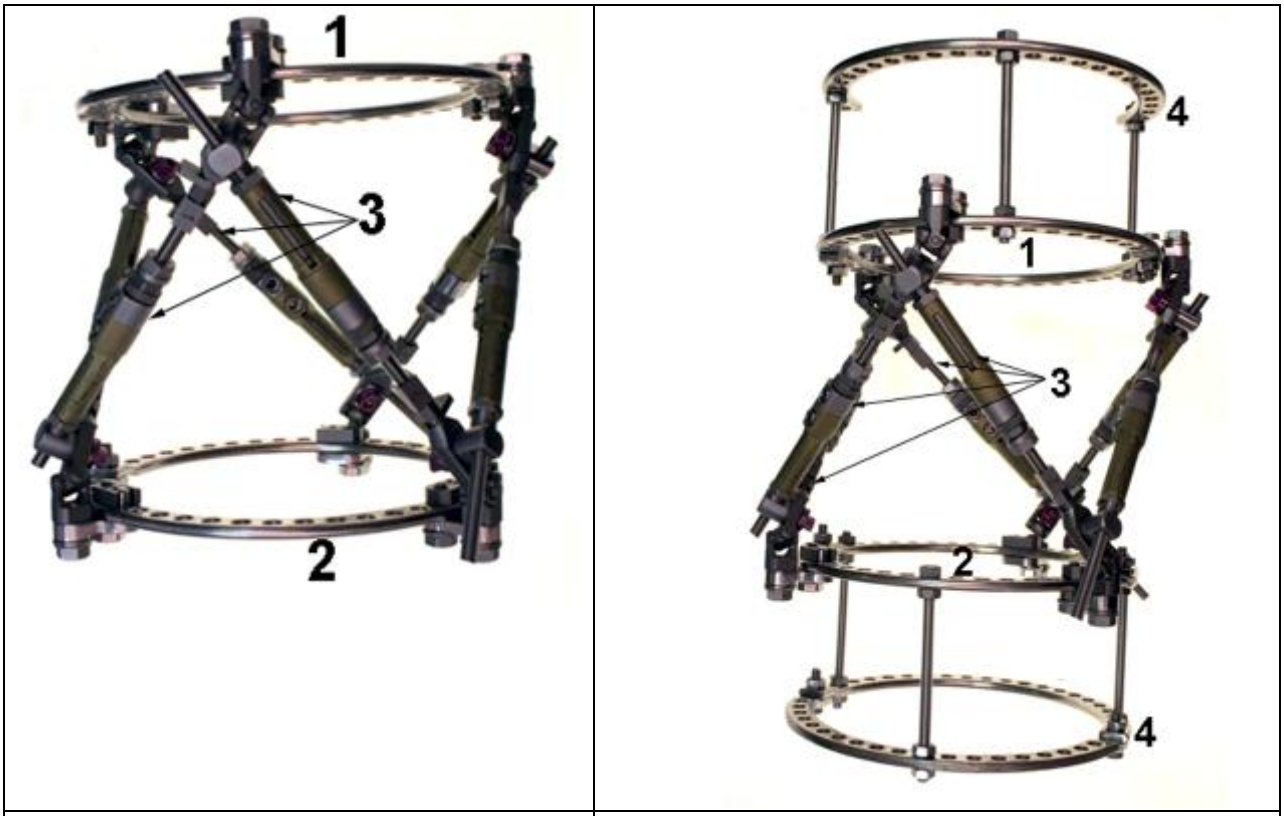
Fig. 3a-c. Orthopaedic hexapods. a – device created in Ilizarov Russian Research center. b – Taylor Spatial Frame device. c - Ilizarov Hexapod System device

First orthopedic hexapods operating on computer navigation principles appeared in USA and Germany. Those are Taylor Spatial Frame – TSF (Fig. 3b), with its usage having started in 1994 and Ilizarov Hexapod System device – IHS (Fig. 3c), created in 1999 (Seide K. et al., 1999). Offering the possibility to implement deformity correction with mathematical precision without resorting to repeatative changes of unified reduction nods, these devices enjoy growing popularity in fracture treatment, in particular of long bones (Paley D., 2005; Seide K. et al., 2008; Solomin L.N. et al., 2009). In 2006, in Russia, original transosseous hexapod was created – Ortho-SUV Frame.

Sometimes it is mistakenly mentioned in literature, that all known in orthopaedic hexapods work using Stewart platform (Taylor J.C., 1997; Seide K. et al., 1999; Paley D., 2005). However actually, IHS *и* TSF devices in their structure are closer to Gough's and Ceppel's platforms (Fig. 2a,b). Ortho-SUV device just outwardly reminds Stewart platform: operating on basis of unique Solomin-Utehin-Vilenskij system, it has kinematics, which is quite different from those featured by all known hexapods. Due to improvements, Ortho-SUV succeeds its analogs by a number of design features, its reductive potential and rigidity of the osteosynthesis. Additionally, Ortho-SUV frame is equipped with advanced software (Solomin L.N. et al., 2009; Solomin L. et al., 2008).

2 Design of Ortho-SUV Frame

Ortho-SUV Frame (Fig. 4) consists of two external supports: basic (1) and mobile (2). Six struts connected in series (3) unite them. Taken all together, these parts constitute "universal reduction nod" mentioned above. Basic support, with the help of transosseous elements, fixes the main bony fragment. In the mobile support, respectively, the bony fragment to be transported is held. If necessary, the rigidity of osteosynthesis might be increased by using additional stabilizing supports (4).



a b

Fig. 4a,b. Ortho-SUV frame design. a – basic set; b – set completed with stabilizing supports; 3 – struts; 4 – stabilizing supports

Ortho-SUV Frame's set (Fig. 5a) includes:
- six uniquely designed telescopic rods– struts (b);
- six simple plates (c);
- six Z-shaped plates (c);
- six strut labels (d);
- six strut number markers (d);
- spanner wrenches (e);
- screwdriver (e);

a

b

c d

e

f

Fig. 2.9.5a-f. A standard Ortho-SUV Frame's set. a – full set; b – set of struts; c - plates – simple and Z-shaped; d – X-ray positive strut labels and strut number markers; e – wrenches and a screwdriver; f – device for changing strut lengths and triangle legs

2.1 Design of strut of an Ortho-SUV Frame

A strut consists of three main elements: a joint, a threaded rod M6 and a strut length changing unit (Fig. 6).

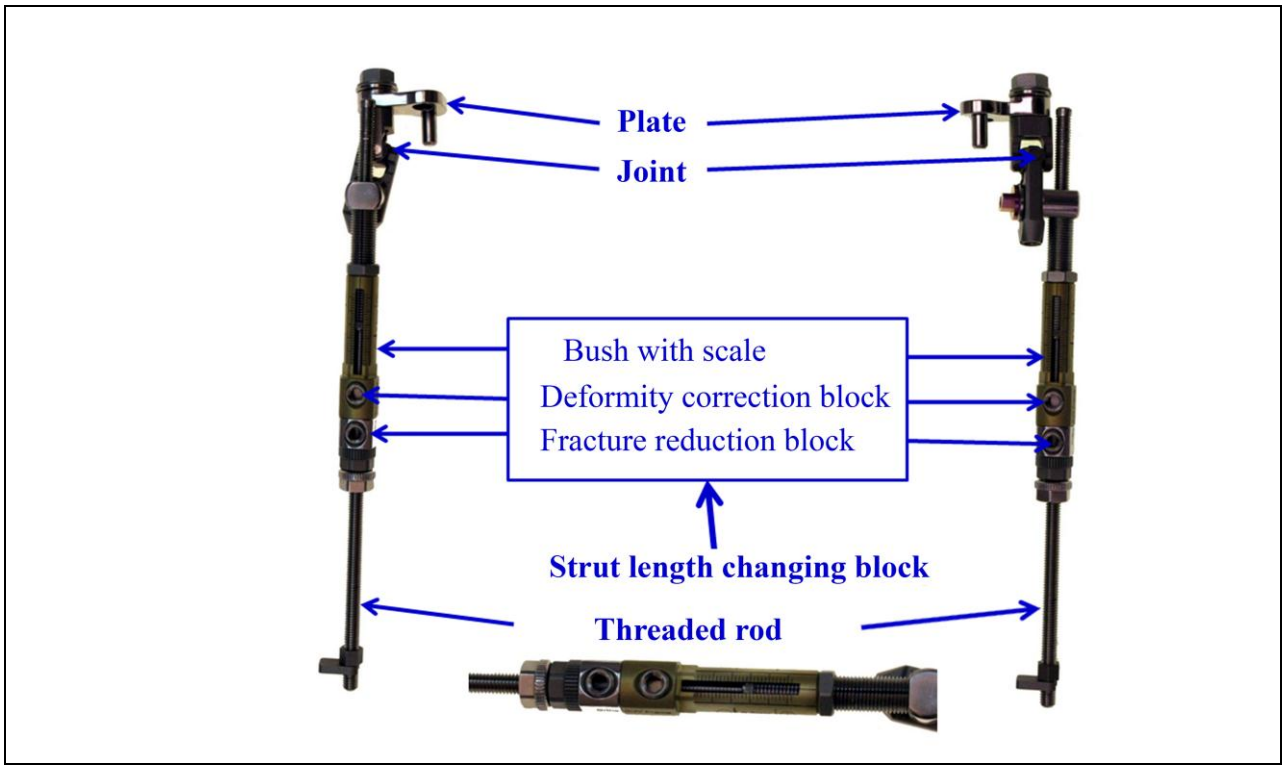
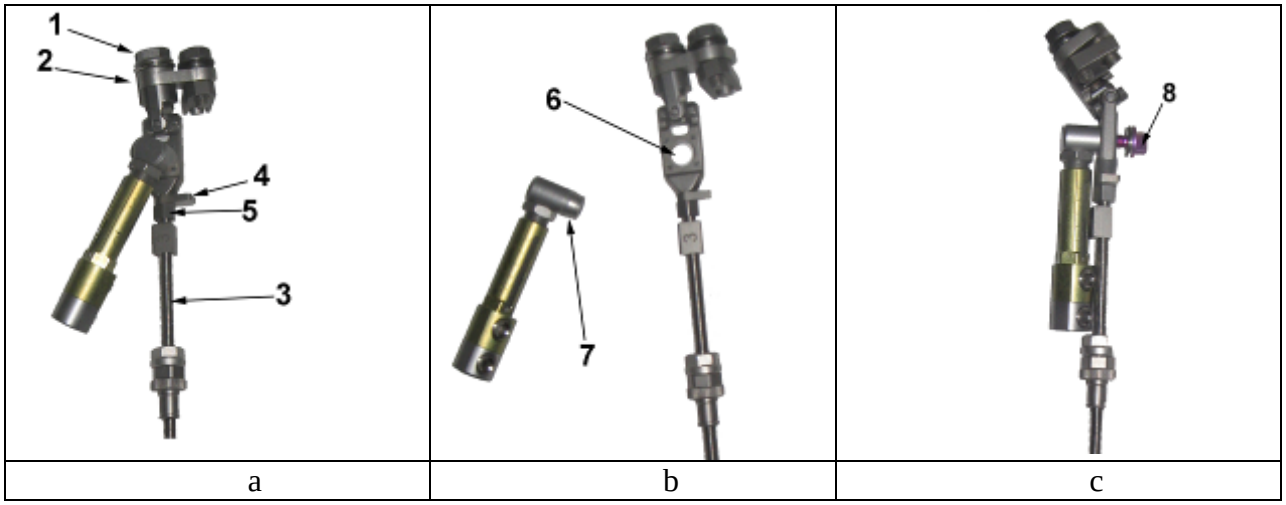


Fig. 6. Strut's of an Ortho-SUV Frame design

Joint (Fig. 7), consists, in its turn, of bolt (1) serving to fix the joint to plate (2) and a hole (6) to connect it with the adjacent strut. To fasten the strut to the joint of the adjacent strut one has to connect axle (7) with red screw (8). There is a hole M6 at the joint's butt-end to connect with threaded rod (3). The threaded rod is fixed to the joint using small lock nut (5) and a blocking washer (4).

Strut length changing unit (Fig. 8) consists of fracture reduction unit (1) and deformity correction unit (2).



a b c

Fig. 7a-c. Design of a joint of Ortho-SUV Frame's strut. a – Joint in conjunction witn adjacent strut; b – joint linked to adjacent strut by red screw; c – adjacent strut disangaged; 1 – bolt; 2 – simple plate; 3 – threaded rod; 4 – blocking washer - «footstep» type; 5 – small lock nut; 6 – hole for connection with an adjacent strut; 7 – axle for connection with an adjacent strut; 8 – butterfly screw (red-colored)

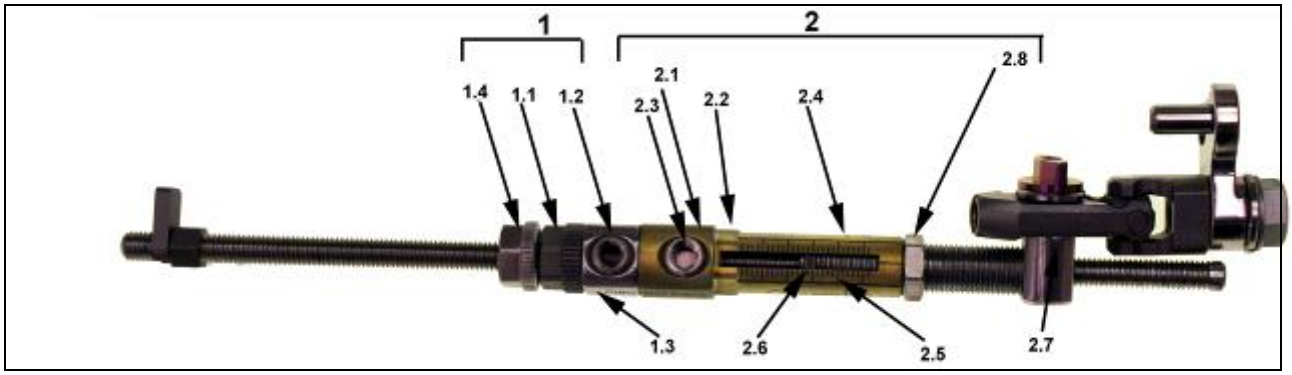


Fig. 2.9.8. Design of strut length changing unit. 1 – fracture reduction unit, where: 1.1 – connecting threaded bush; 1.2 – fixing screw №1; 1.3 – body; 1.4 – lock nut. 2 – deformity correction unit where: 2.1 – body; 2.2 - hexahedron for M12 wrench; 2.3 – fixing screw №2; 2.4 – threaded bush; 2.5 – scale with 1 мм division; 2.6 – indicator showing strut length change; 2.7 – axle to connect joint of an adjacent strut, 2.8 – lock nut M12

Fracture reduction unit (Fig. 8) consists, in its turn, of threaded bush (1.1), body (1.3), fixing screw #1 (1.2) и lock nut (1.4). With fixing screw loosened, connecting threaded bush can be moved along the threaded rod (Fig. 9). This design feature makes it possible for the frame to operate in «fast struts» mode, used for manual fracture reduction (see section 4.1).

Fig. 9. Design fracture reduction unit: 1.1 – connecting threaded bush

Deformity correction unit (Fig. 8) consists of: body (2.1) equipped with hexahedron for M12 wrench (2.2), fixing screw №2 (2.3), threaded bush (2.4), axle for connection with an adjacent strut's joint (2.7), lock nut M12 (2.8). One should take into account, that threaded rod and threaded bush have to have different thread hands. Bush of deformity correction unit has scale with 1mm division (2.5). There is also indicator of strut length change (2.6).

2. 2 External supports

Supports from any circular external fixation devise may be used to assemble an Ortho-SUV Frame (Fig. 10a,d,g). Additionally, supports representing 1/2, 2/3, 5/8 of a ring (Fig. 10b,e,h) might be utilized. Supports of any shape (triangle, oval, rectangle) are acceptable (Fig. 10 c,f,i).

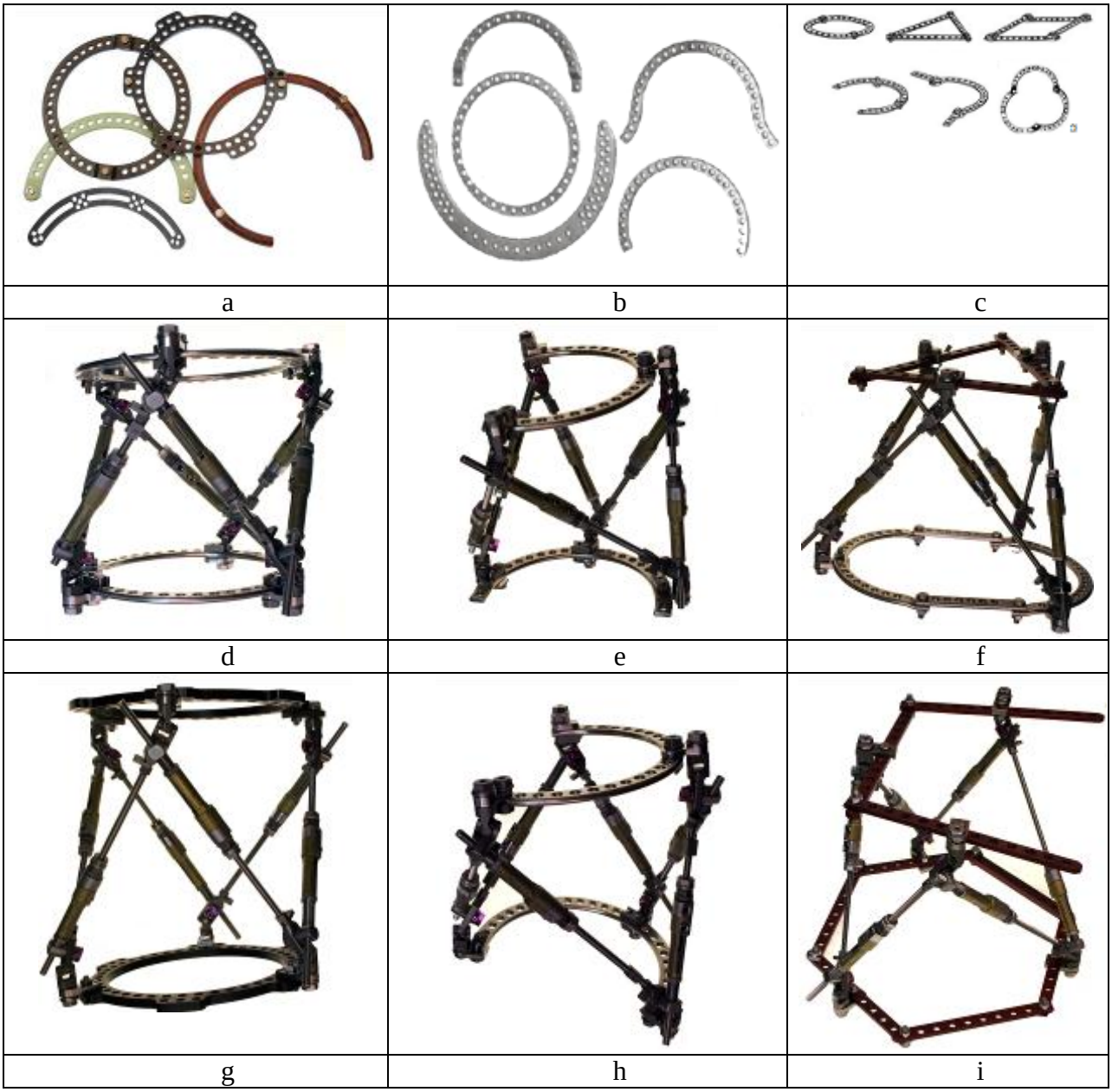


Fig. 10a-i. While assembling an Ortho-SUV Frame, supports of various shapes and brands might be utilized: a,d,g – supports from a range of circular external fixation devices are used; b,e,h – application of 1/2, 2/3, 5/8 of ring; c,f,i – usage of variosly-shaped supports (oval, triangle, polygon)

3 Ortho-SUV Frame assembling

Quantity of supports in frame's modules, quantity and type of transosseous elements to insert in each case are chosen on the basis of knowledge in the biomechanics of external fixation and following principles of a method of external fixation frame assembly (Solomin L.N., 2008). One precondition to observe is that degree of fixation rigidity for any given bone fragment has to be sufficient to exclude any correction errors in the process of moving one module relatively to another.

3.1 Assembling universal reduction unit

"Universal reduction unit" of Ortho-SUV Frame consists of six struts supposed to be connected in certain order (Fig 11 a,b). Special removable clips are used to mark their numbers (Fig. 2.9.11a).

a

b

Fig. 11a,b. Set of struts for an Ortho-SUV Frame. a – full set; arrows show number indicators – clips; b – struts interconnected

Struts are fastened (Fig. 12) to supports using simple (1) or Z-shaped plates (2).

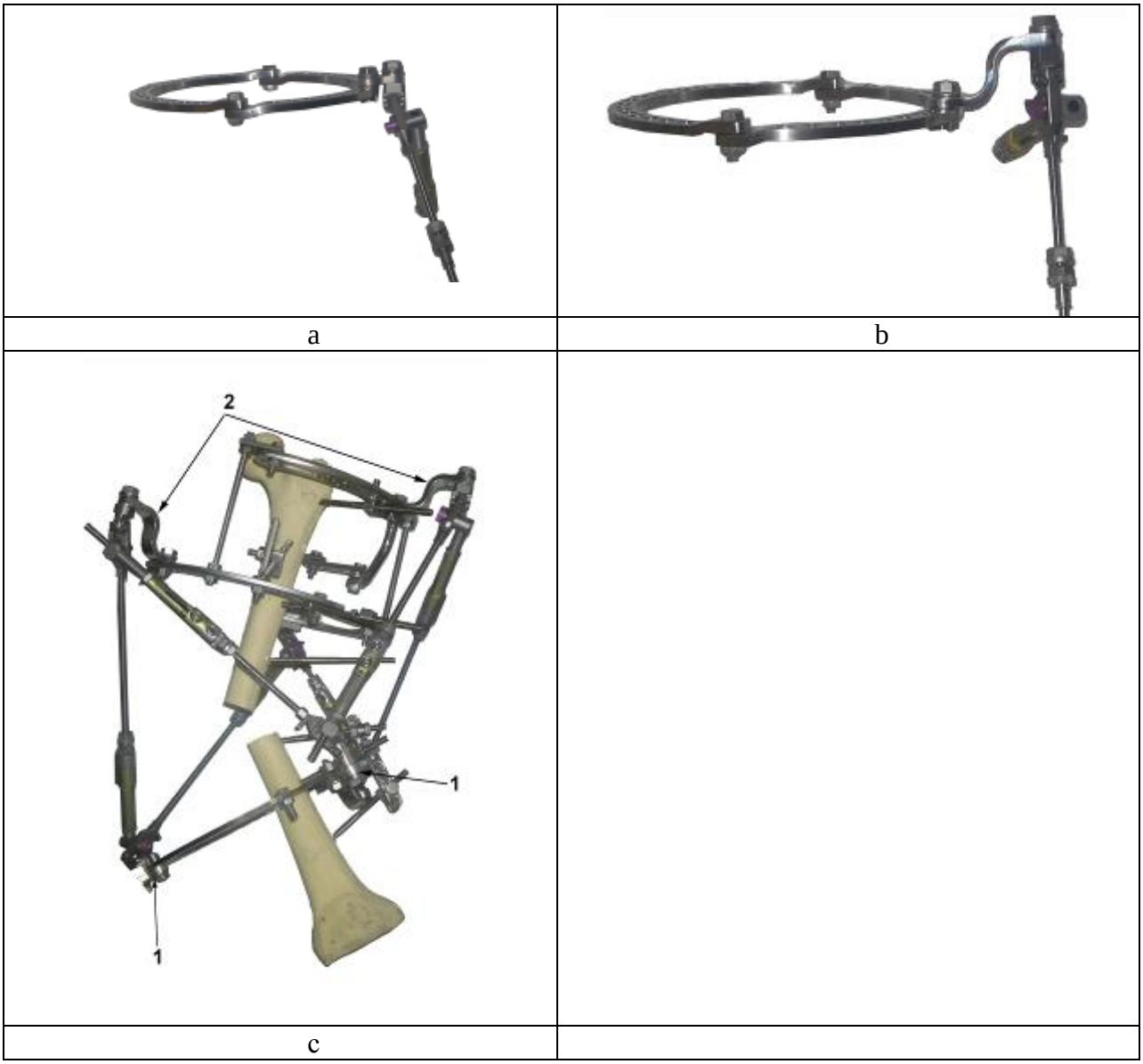


Рис. 12a-c. Frame struts are fastened to supports. a – using simple plate; b – using Z- shaped plate; c – single plate applied (1) Z-shaped plate applied (2). NB: Struts can be fixed not only to basic supports, but to stabilizing supports as well

Struts are fastened to both basic and mobile supports in three points. Starting point of a frame assemblage is with joint of strut №1 situated at any point of front half-round of basic ring. Two rules are to be observed:

1. «Red screws rule»

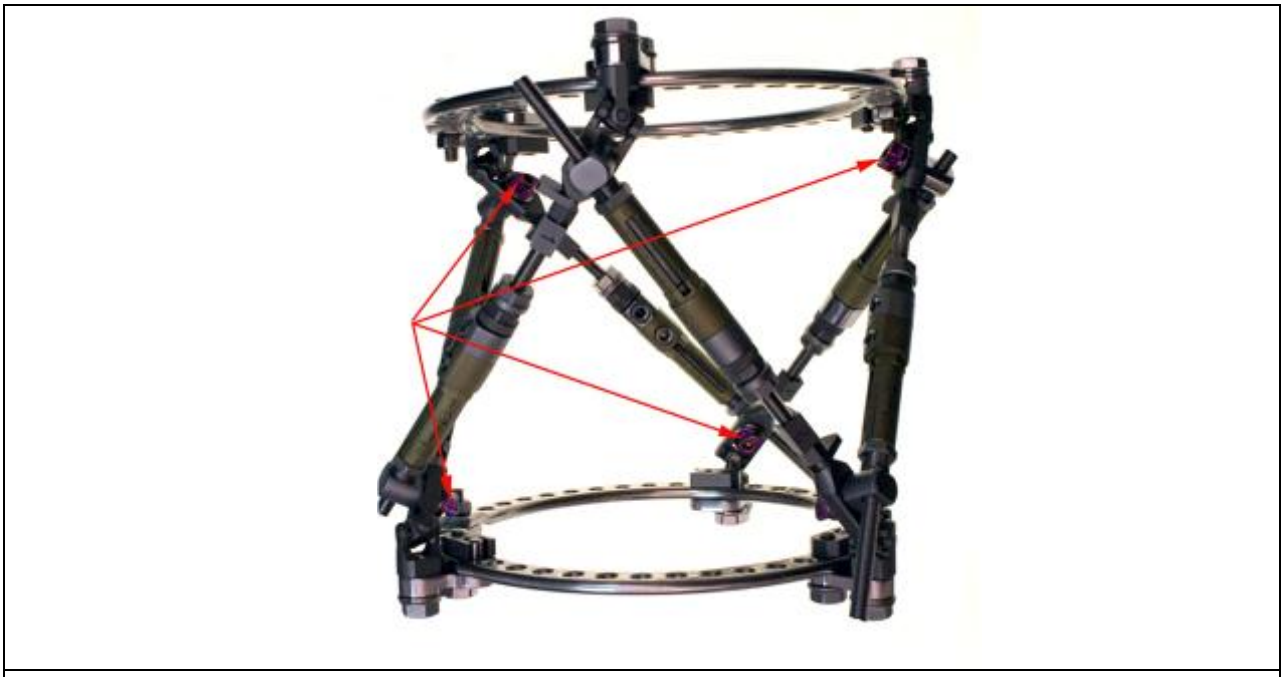
In the process of connecting struts to each other and fastening them to supports, red-colored screws should always be positioned along the inner side of the struts (Fig. 13a).

2. «Watch rule»

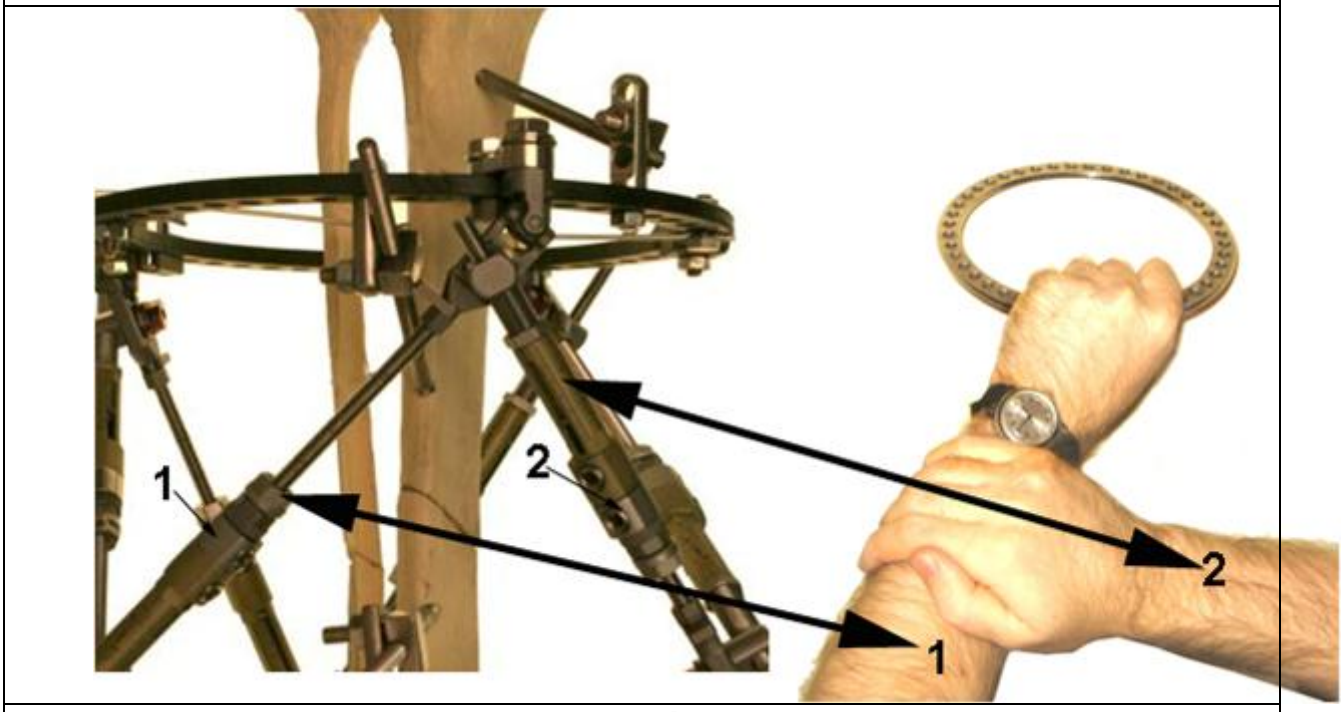
#1 strut always, no matter what segment it is linked with, positions itself at the left and links with the joint fixed to basic support (Fig. 2.9.13b). This strut is symbolized by left arm with watch on. №2 strut is adjusted to the joint of strut № 1 and then heads away from it to the right and down. This strut is symbolized by right hand pointing to the watch.

Positioning of struts №1 and №2 should always comply with this rule no matter whether the frame is applied to left or right limb (Fig. 13c). Further numbering is implemented counter-clockwise (Fig. 14).

Every joint is numbered in accordance with a strut which “gets into” it (Fig. 15). Thus joints №№ 1, 3 and 5 are fastened to basic (proximal) support; joints №№ 2, 4 and 6 – to the mobile (distal) support.



a



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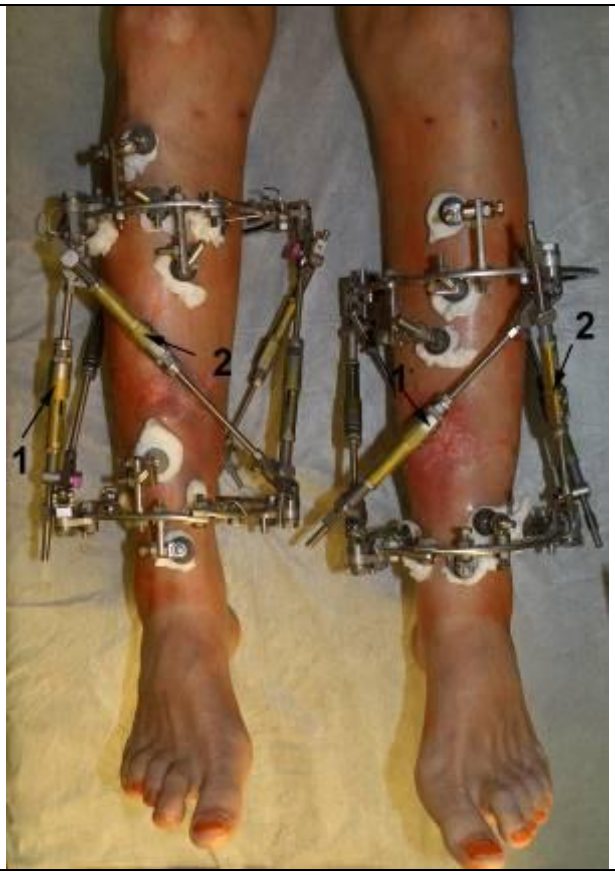
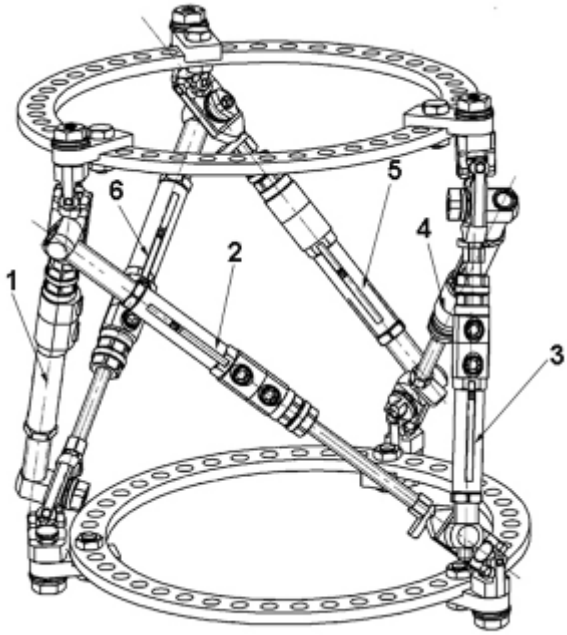
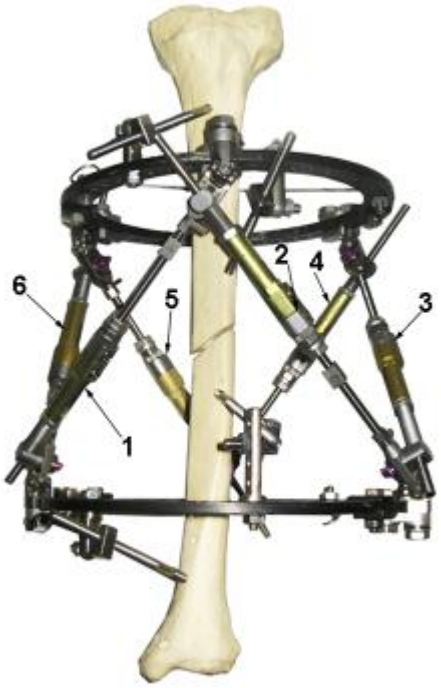


c

Fig. 2.9.13a-c. Struts connected. a – arrows point to red-colored screws supposed to be positioned “inside” of the frame; b - mnemonic «watch rule»: 1 – strut №1 corresponds to the left hand with watch on, 2 – strut №2 corresponds to the right hand, pointing to the watch; c – no matter which side is involved positioning of struts №1 и №2 complies to the «watch rule»



a



b

Рис. 14a,b. Struts are placed counter-clockwise, proceeding from the first one: a – scheme; b – a model

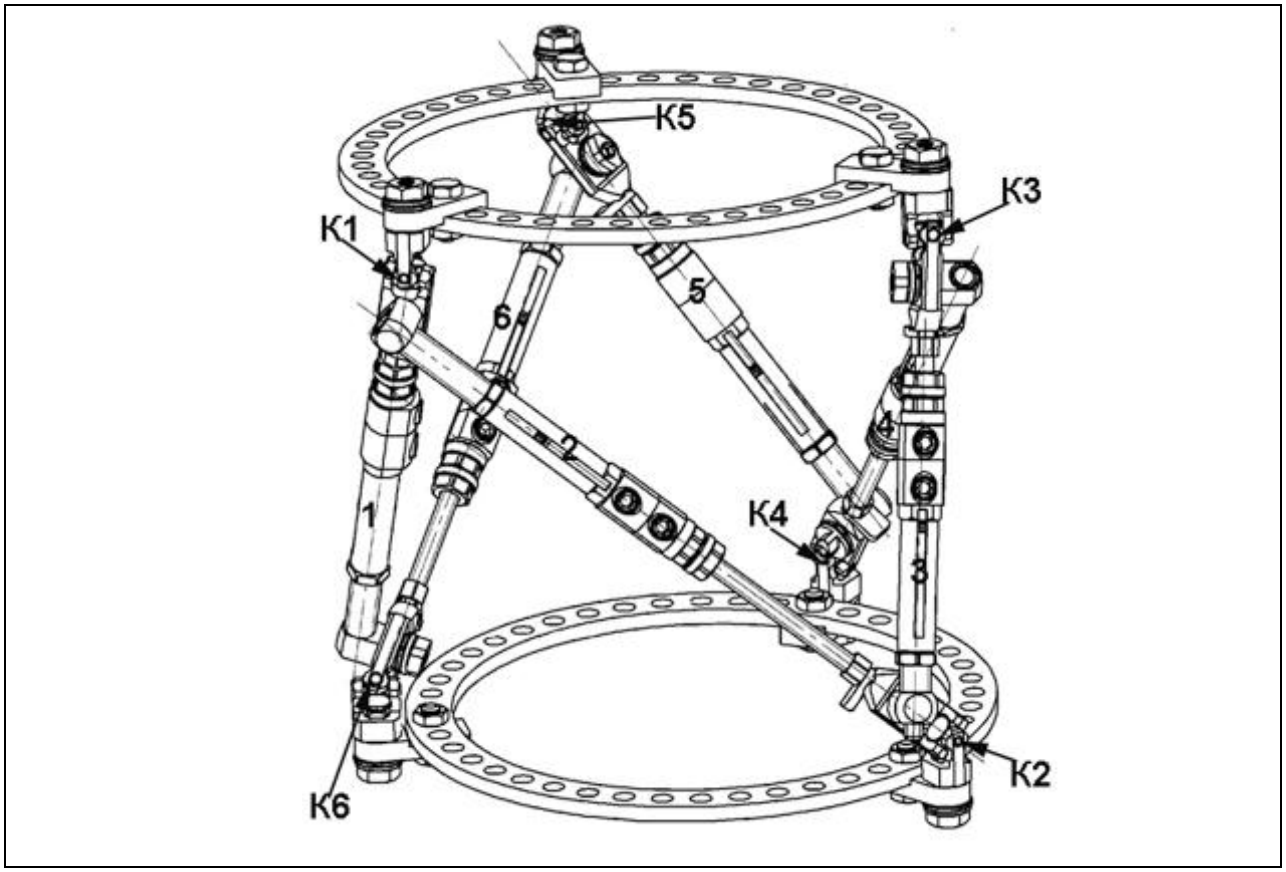


Рис. 15. Joint numeration. Joints 1, 3 and 5 correspond to struts 1, 3 and 5 and are fixed to the proximal (basic) support. Joints 2, 4 and 6 correspond to struts 2, 4 and 6 and are fixed to the distal (mobile) support

4 Modes of Ortho-SUV Frame operation

For reasons relating to practical application it is accepted to move distal (mobile) support relatively to proximal (static, basic) support. Length change of even one of the struts will cause the mobile support to dislocate in three plains. By changing lengths of every strut, displacement of mobile support to required direction and distance is achieved. The amount of length change for every strut is calculated by computer program.

There are 2 modes of operation for an Ortho-SUV Frame:

1. «Fast struts» mode;
2. «Chronic deformity correction» mode.

4.1 «Fast struts» mode

This mode is used for acute fracture reduction or when deformity correction is implemented with visual control or fluoroscopy. The starting point of procedure is to untighten large lock nuts and move them - by rotating – away from strut length changing unit. Fixing screws №1 are loosened using hexahedral screwdriver (Fig. 16a). Connecting threaded bushes are moved behind the lock nuts (Fig. 16b). Next step is reduction as such implemented by manual moving of supports relatively to one another (Fig. 16c). Connecting threaded bushes are moved then along the threaded rods until each one “locks with” its respective strut length changing unit. Fixing screws №1 are fixed (Fig. 16d).

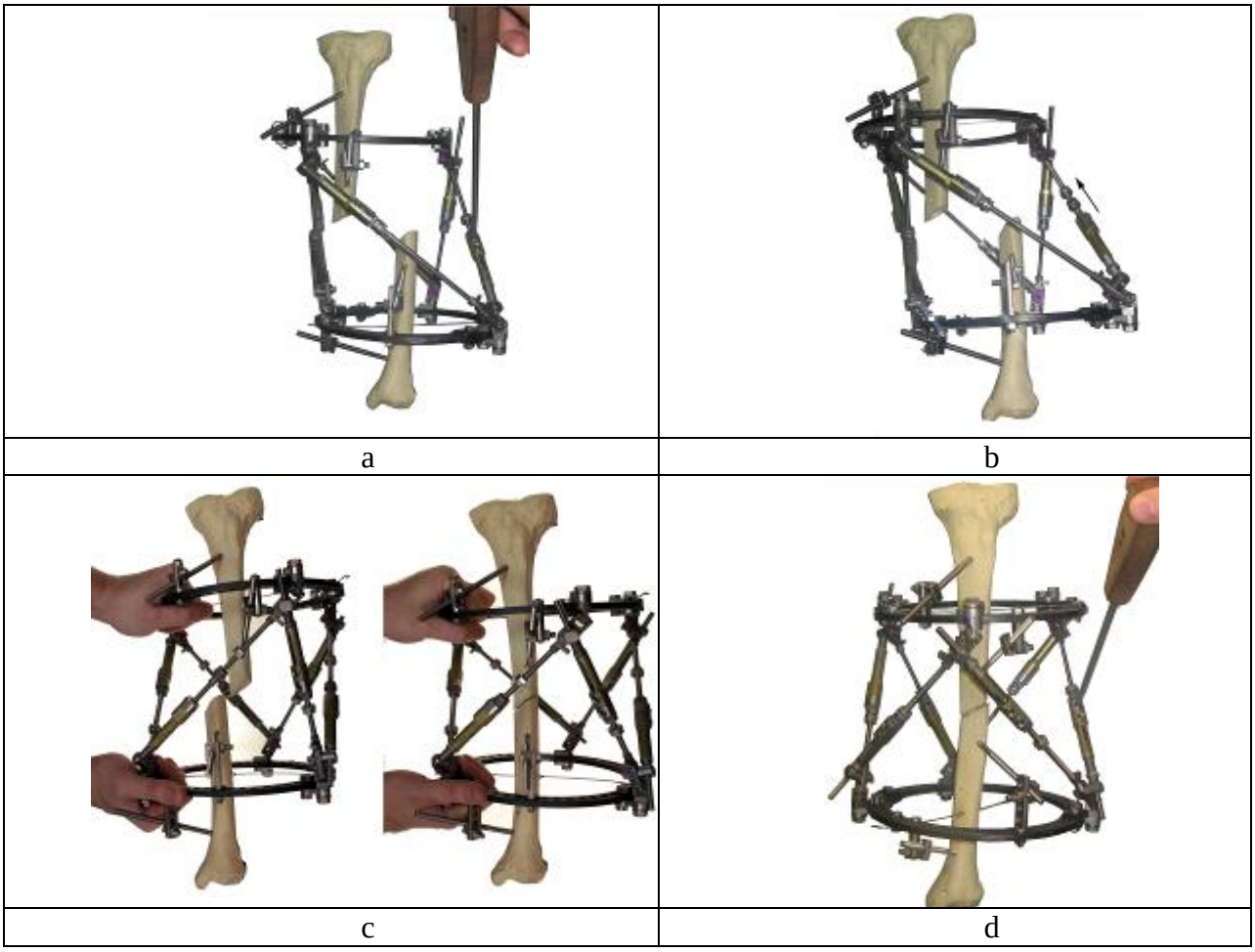


Рис. 16a-d. Fracture reduction in «fast struts» mode: a – fixing screws №1 of all the struts are being loosened; b – connecting threaded bushes are moved along the threaded rods; reduction is implemented; d – connecting threaded bushes are moved along the threaded rods until each one gets into its own strut length changing unit; fixing screws are tightened

4.2 «Chronic deformity correction» mode

This mode is applicable when deformity correction - or fracture reduction - takes place over an extended time period. Computer program calculates which struts are to be lengthened or shortened. Strut length changing unit comes with a scale. For a strut supposed to be lengthened, the strut length indicator has to be set in its extreme "-" (minus) position. If a strut is intended for shortening, the indicator has to be set in its extreme "+" (plus) position.

To set the indicator into its new position, do the following:

1. Loosen the lock nuts.
2. Using screwdriver, untighten the fixing screw №2 of deformity correction unit (Fig. 17a).
3. By opposing hand motions, rotate deformity correction unit and fracture reduction unit in opposite directions relatively to one another (Fig. 17b). If strut's length had been minimal, the deformity correction unit is rotated clockwise; if strut's length has been maximal, the deformity correction unit is rotated counter-clockwise. In the process of deformity correction and fracture reduction units counter-rotating, the strut length does not change and bone fragments do not displace.
4. Tighten the fixing screw №2 and lock nuts.

Sometimes scale length does not suffice for the correction of fragment displacement to be completed. In such cases the whole procedure has to be repeated.

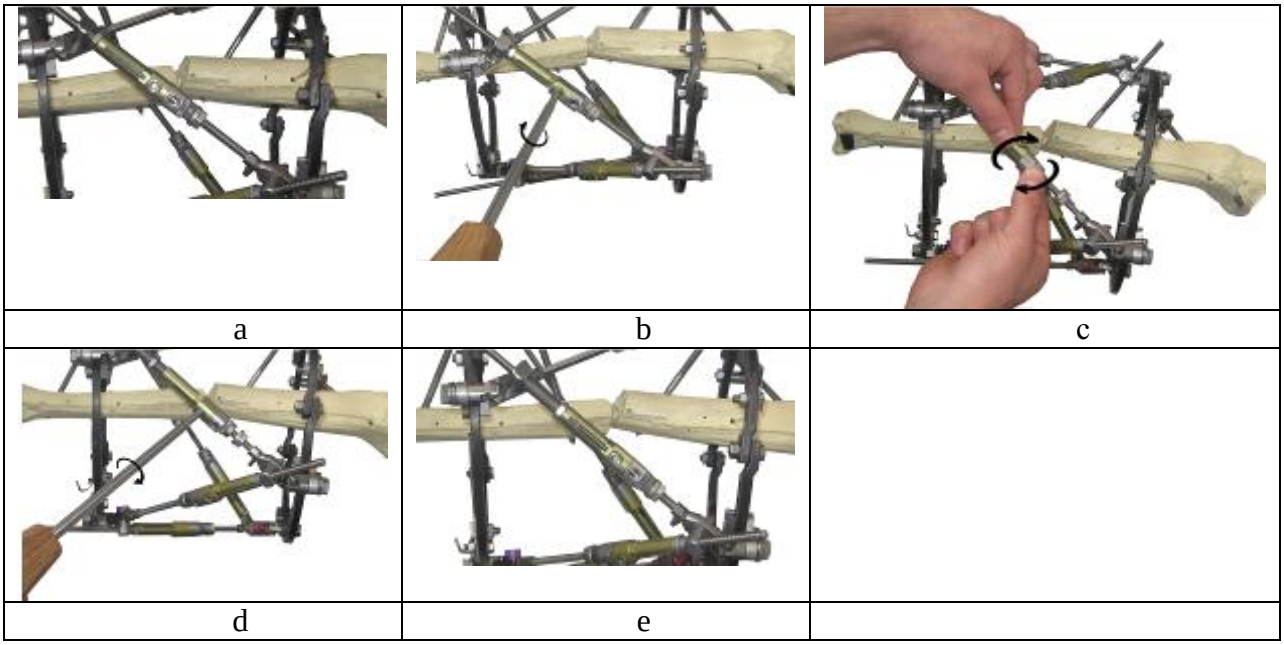


Fig. 17a-c. Equipping of a strut: a – scale before procedure: indicator is set in its extreme «+» position.; b – loosening of fixing screw №2; deformity correction unit and fracture reduction unit are counter-rotated; d – fixing screw №2 is tightened; e – scale after the procedure: indicator is in its extreme «-» position; strut length has not been changed!

To *change a strut's length*, lock nuts have to be loosened and body of deformity correction unit rotated (рис. 18a,b). Clockwise rotation of the body causes strut length to be increased while counter-clockwise rotation shortens the strut. Body of deformity correction unit is marked respectively: "+" and "-". The amount of change in strut length is estimated by the position of indicator on the scale relatively to its initial position. When the necessary length is achieved, lock nut is moved back along the strut, thus fixing its length. This procedure is repeated to all the struts that had their length changed.

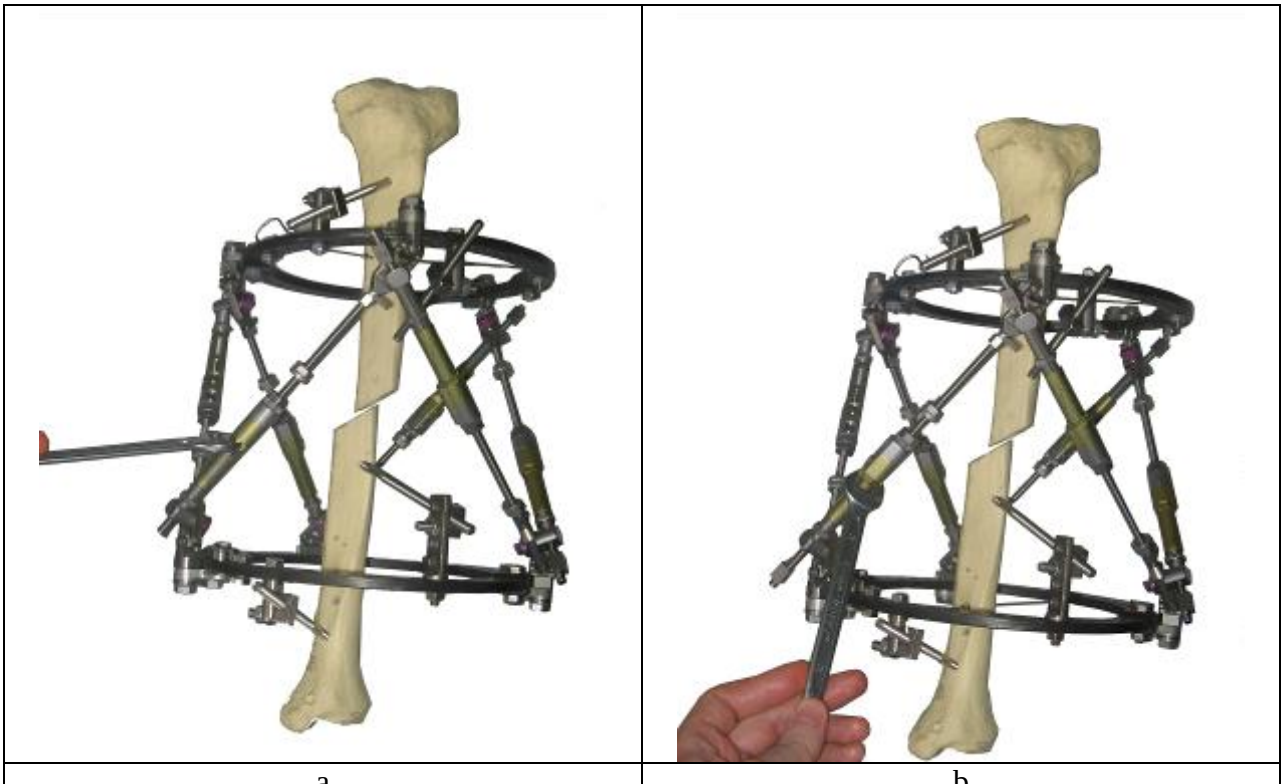


Рис. 18a,b. «Chronic deformity correction» mode

As it has been pointed out, for precision in controlled relocation of bone fragments it is necessary to calculate the amount of length change for every strut. There is a special computer program for this purpose.

5 Computer program for Ortho-SUV frame

Software enclosed with Ortho-SUV frame, calculates the amount of strut length changes necessary for deformity correction or fracture reduction. To do so, it needs to be given parameters of two types:

1. Those measured on the frame (12 parameters) and during making X-rays (2 parameters);
2. Those measured on X-ray films (14 parameters).

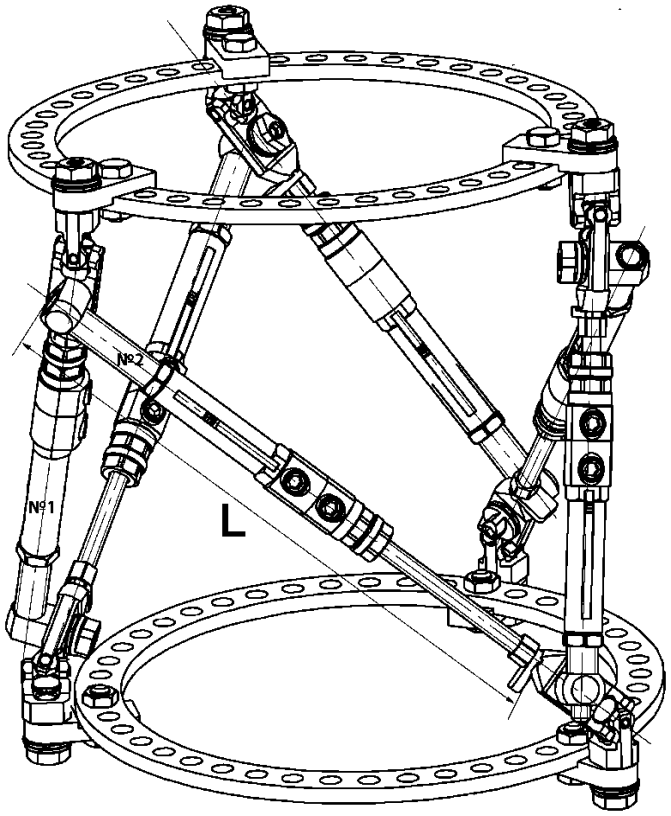
Type one parameters are obtained using measuring tools. The program own measuring instruments are used to acquire parameter values of type two.

5.1 Parameters, measured on the frame

12 parameters are measured on the frame:

- strut lengths (6 parameters);
- side lengths (6 parameters) of triangles - with centers of bolts that fix strut joints to the support as their apexes;

Strut length is a distance between strut joint and end of the strut length changing unit (Fig. 19).



a

b

c

d

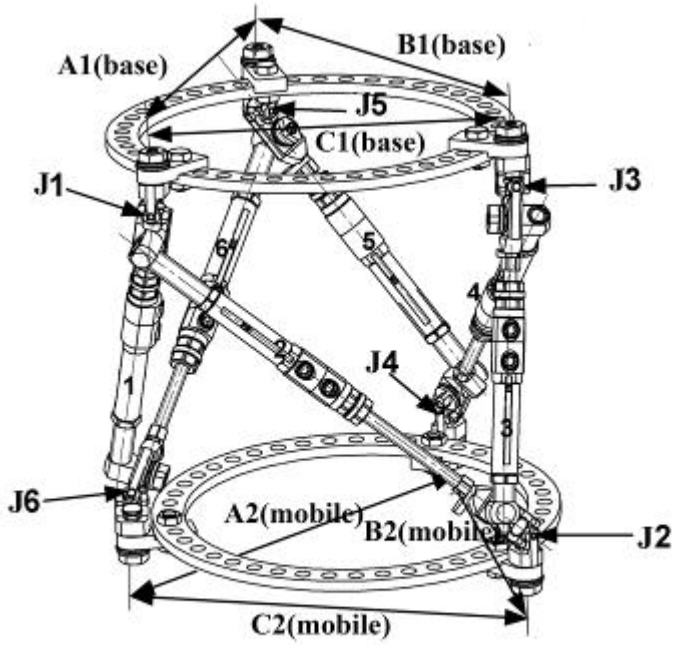
Fig. 19a-d lengths measurements: a – strut length "L" is measured between strut joint and ending point of strut length changing unit; b – by using special tool; c – by means of ruler (tape-line); d – with laser range-finder

Sides of triangles are measured between centers of bolts that fix joints to plates (Fig. 20a,b). It is an error to measure these distances between centers of bolts that fix plates to supports!

For basic support, triangle sides are indicated as A1 (Base), B1 (Base), C1 (Base). Thus, A1 (Base) is a distance between joints №1 and №5; B1 (Base.) is a distance between №5 and №3; C1 (Base) – a distance between joints №3 and №1.

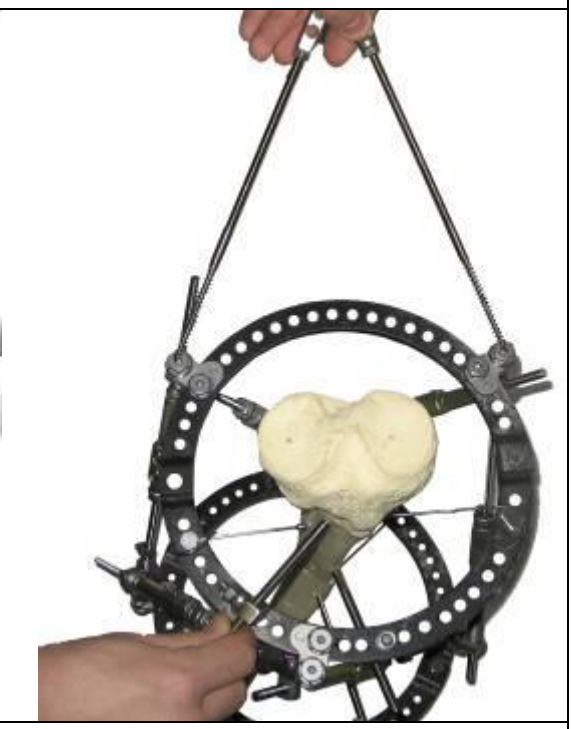
For mobile support, triangle sides are indicated as A2 (Mobile), B2 (Mobile), C2 (Mobile). Thus, A2 (Mobile) is a distance between joints №6 and №4; B2 (Mobile) – between joints №4 and №2; C2 (Mobile) – between joints №2 and №6.

Measurements are taken using special measuring tool (Fig. 20b).

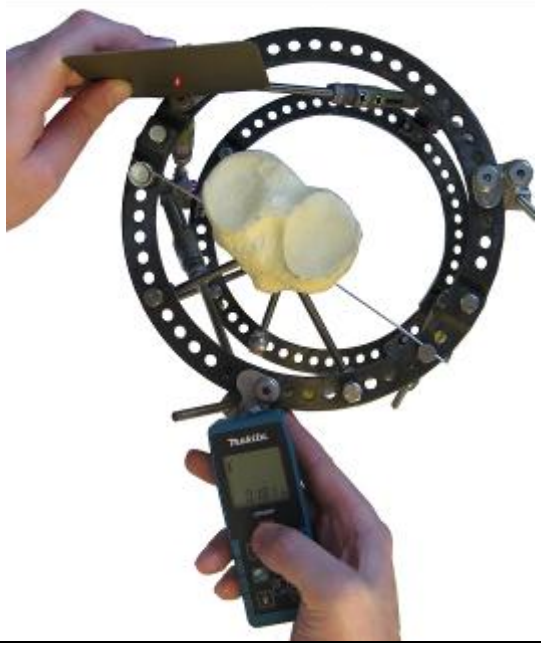

A1(base)
B1(base)
J5
C1(base)
J1
J3
6
5
4
2
J4
1
3
J6
A2(mobile)
B2(mobile)
J2
C2(mobile)

a

b



c



d

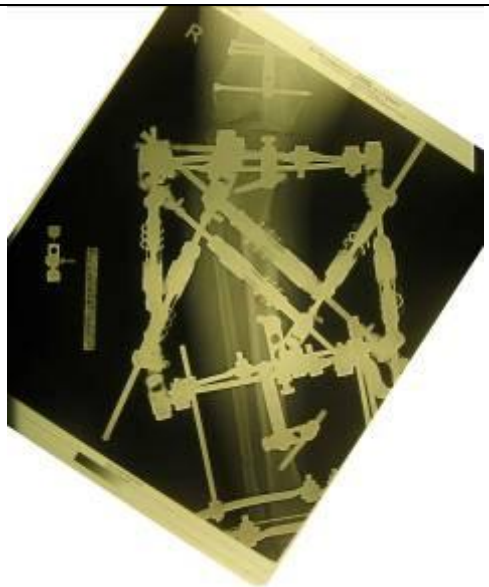
Рис. 20a-d. Measuring sides of triangles with centers of joint's bolts as their apexes; a – schemes; b – measurement is taken using special tool; c – measurement is taken using a device assembled using parts of Ilizarov's frame; d – the same, using laser range-finder

5.2 Parameters measured on X-ray films

While making radiograms intended to become parameter material for computer program, one has to follow, apart from the standard rules (chapter 1.10.1), some additional ones:

1. Image field has to cover as many joints and struts as possible. Therefore plate holders less than 30 см in widths are not expedient to use (Fig. 21).

a



b

c

d

Fig. 21a-d. Image field, beam center; a – when a "narrow' film is used, quantity of struts and joints visualized will not suffice for necessary parameters to be measured; b – image field encompassing most of struts and joints. On struts, "bar-cods" indicating strut numbers are visible. The arrow points to the beam center; c – self-adhesive X-ray positive mark for visualizing beam center; d – mark fixed on the film cassette

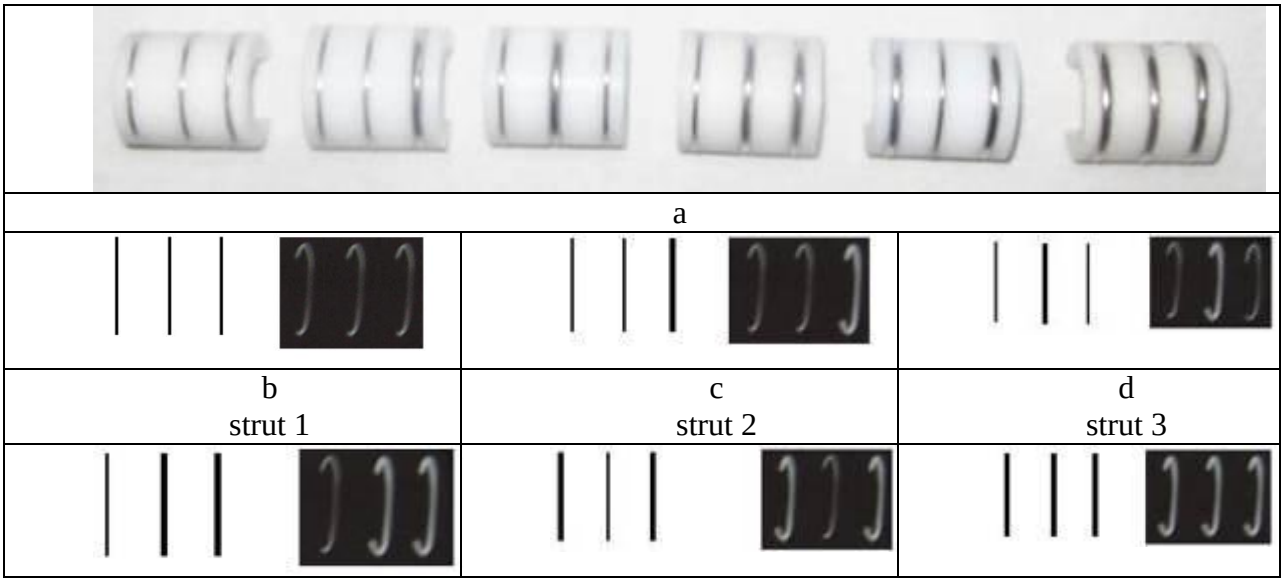
Focal distance has to be measured. For focal distance is taken a distance between anode of X-ray tube and a film cassette. X-ray units are often equipped with focal distance sensors or their own, fixed tape-lines (Fig. 22). If there is no measuring device provided with an X-ray unit, focal distance is measured, using tape-line, in millimeters.

NB! When a radiopaque ruler is used (for scaling – step 4 in the program), focal distance is measured between anode and a ruler. Therefore, if the ruler is placed directly on the top of plate-holder, the general rule works. But when a plate-holder is placed inside of its bin while the ruler is positioned on the top of X-ray table, for focal distance is taken the distance from anode to the ruler.

Fig. 22. Measuring of focal distance (two parameters: for AP and lateral views)

3. X-ray *beam center* has to be indicated on the roentgenogram. For this purpose, a small, (about of a cent coin in size), usually cross-shaped marker is placed upon plate-holder, upon a point where center of an X-ray tube is projected to (Fig. 21b,c). While performing roentgenogram, make sure that this beam center marker did not overlap with any radiopaque parts of the frame, such as struts or supports.

4. To facilitate strut identification in an X-ray view, special clips – radiopaque markers of strut numbers - are fixed to the struts (Fig. 23a-i).



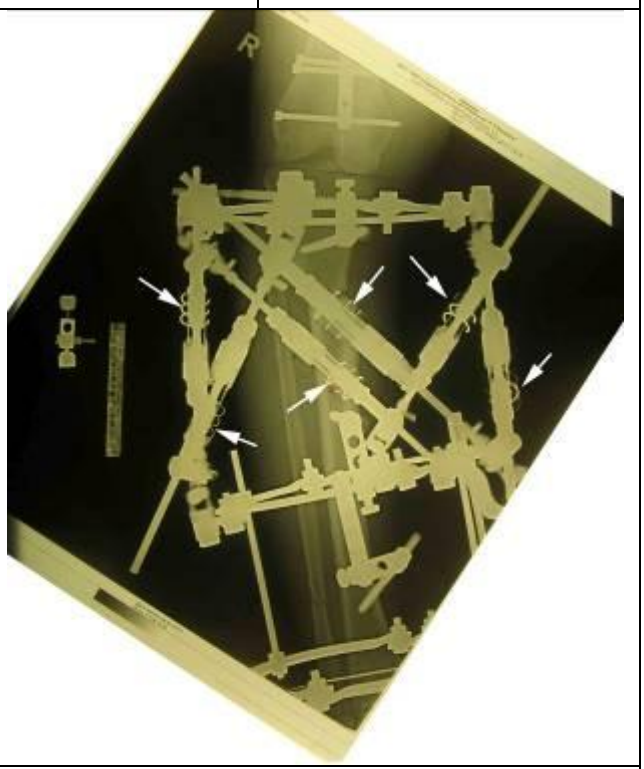
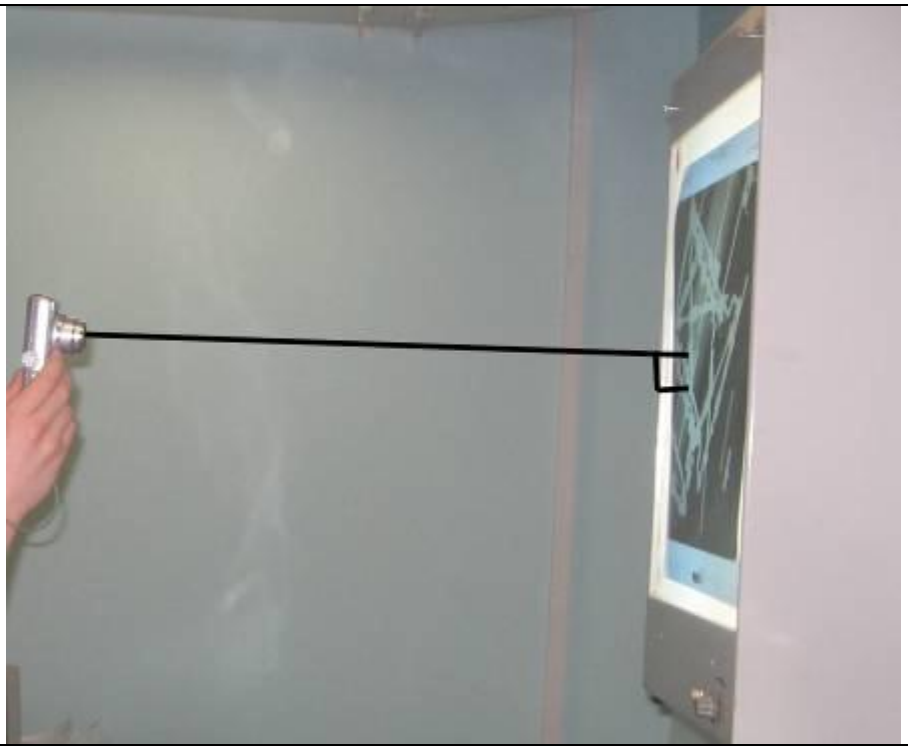
<table>
<tr><td>e
strut 4</td><td>f
strut 5</td><td>g
strut 6</td></tr>
<tr><td colspan="2"> </td><td>  </td></tr>
<tr><td colspan="2">h</td><td>i</td></tr>
</table>

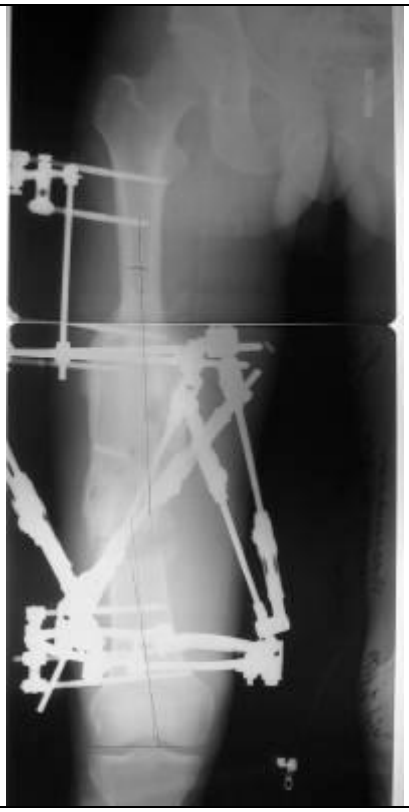
Fig. 23a-i. Strut markers: a – appearance of strut markers; b-g – correspondence between bar-cods and strut numbers; h – strut markers fixed to struts; i – images of strut markers on X-ray (arrows pointing to them)

5. In cases when AP and lateral views for some reason may not be taken tangentially (that is, at right angle to one another), it is acceptable to perform them at the angle not less than 45º. Views that are less than 45º angular to one another make it *impossible* for the computer program to perform calculations.

6. If a radiograph is first made in analog way, it has to be converted into digital form, for instance, by photographing it. In the process, camera lens has to be parallel to the viewing surface of negatoscope, and an X-ray film has to fully fit into the photograph (Fig. 24a,b).



a



b

Fig. 24a,b Converting analog X-rays into digital format; a – the way photographs have to be taken; b – resulting image

5.3 Working with the software

Program for working with «Ortho-SUV» frame is written using “C++ Builder” language. Its volume is about 1400 kb. To install it, copy the executable file on hard disc. Minimal

requirements: IBM PC-compatability, operating system Windows 2000, XP or Vista, processor not worse than DX486, with frequency 1,5 GHz minimum and RAM memory space at least 256 Мб. The installation requires at least 10 Mb of disk space. Color display with resolution 800x600 dots is necessary.

Working with program involves advancing through the sequence of 12 steps. At every step, if necessary, one can return to the previous step. If obligatory actions required at every given step are not performed, advance to the next step is prevented.

Program works with digital roentgenograms saved in variety of formats: bmp, tif, jpg etc.

To start working, double-click “SUV.exe” file. Program window appears. Press the "New document" button. New document will be created with its first page entitled «**Step 1**» (Fig. 25).

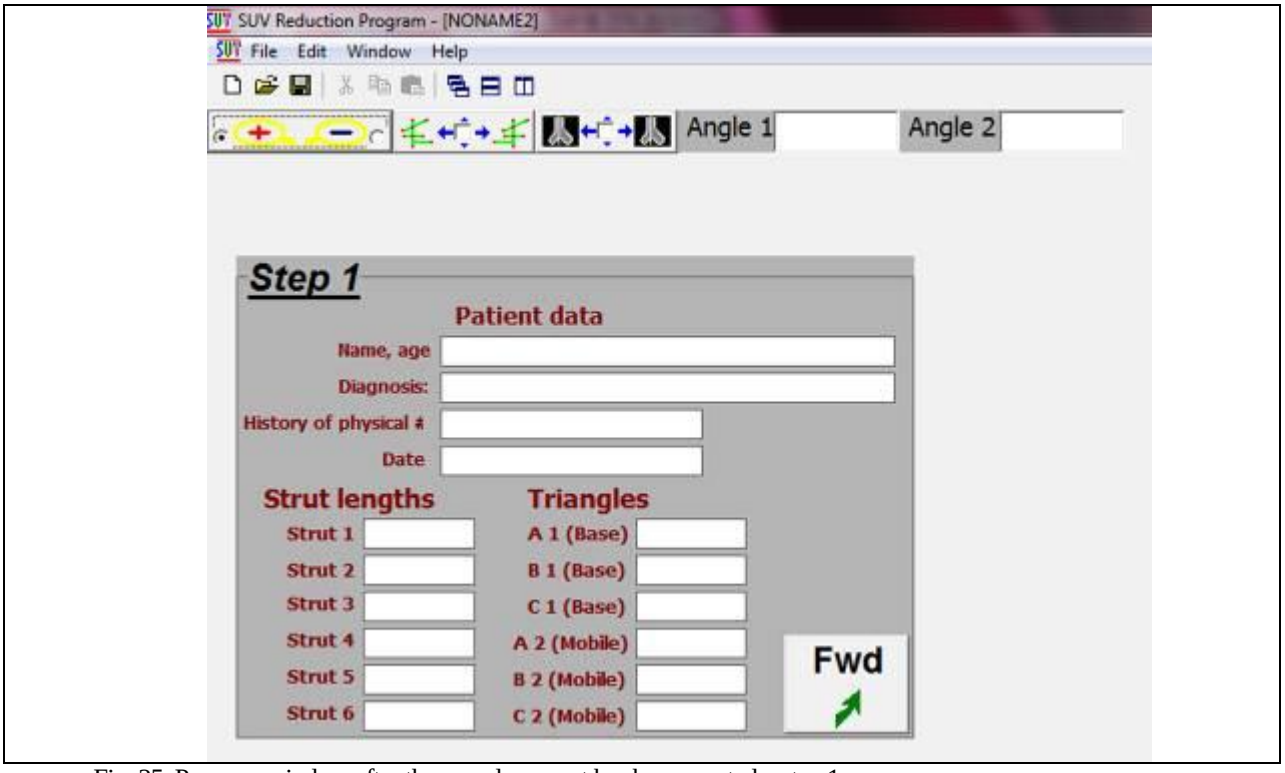


Fig. 25. Program window after the new document has been created – step 1

Following tools are available in the new document window (Fig. 26):

- zoom in/out button (1);
- move fragment markers button (2);
- move roentgenogram images (3);
- Fields displaying angles between axes of bone fragment markers (4);

These tools will be described further, in this step-by-step manual for the “Ortho-SUV” program.

NB! Immediately after the new document (that is, “clinical case”) has been created, it is necessary to save it (command “Save” in “File” menu) with the name corresponding to a patient’s surname. It is recommendable to repeat saving after every step.

NB! If for some reason difficulties occurred (which usually is associated with incorrect usage) it is recommended to quit the program, save the file and send it to the address orthosuv@gmail.com. In accompanying message explain in detail what kind of a problem has been encountered. To resume working, it is usually enough to re-start the program and avoid former mistakes.

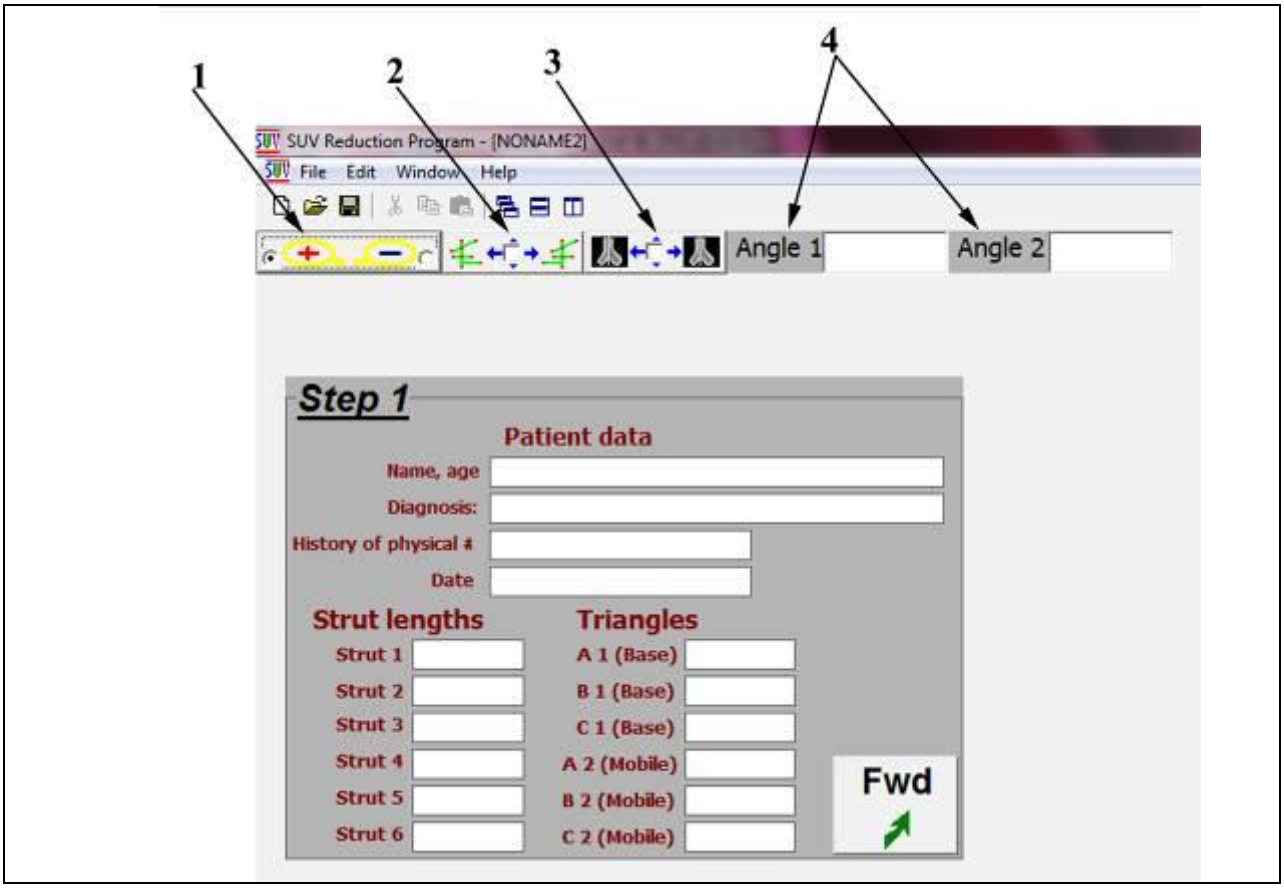


Fig. 26. Program window at step 1: 1 – zoom in/out button, 2 – move fragment markers button, 3 – move roentgenogram images button, 4 – fields where angles between axes of bone fragments are displayed

Step 1 Input of strut lengths and sides of triangles

Fill in the window titled «Patient data» (Fig. 27-1) by typing surname, name, age, and diagnosis of a patient as well as date of modeling.

Fill in the fields «Strut 1 – Strut 6» (Fig. 27-2) by inserting lengths of the corresponding struts. Rules for measuring them are expounded in part 5.1 (fig 19).

Fill in the fields «Triangles A1 (Base), B1 (Base), C1 (Base), A2 (Mobile), B2 (Mobile), C2 (Mobile)» (fig 27-3) by typing in respective side sizes of triangles with centers of bolts that fix strut joints to supports as these triangle's apexes. Rules for measuring triangle sides are expounded in part 5.1 (Fig. 20).

Upon filling in these fields press "Forward" button and move to next step.

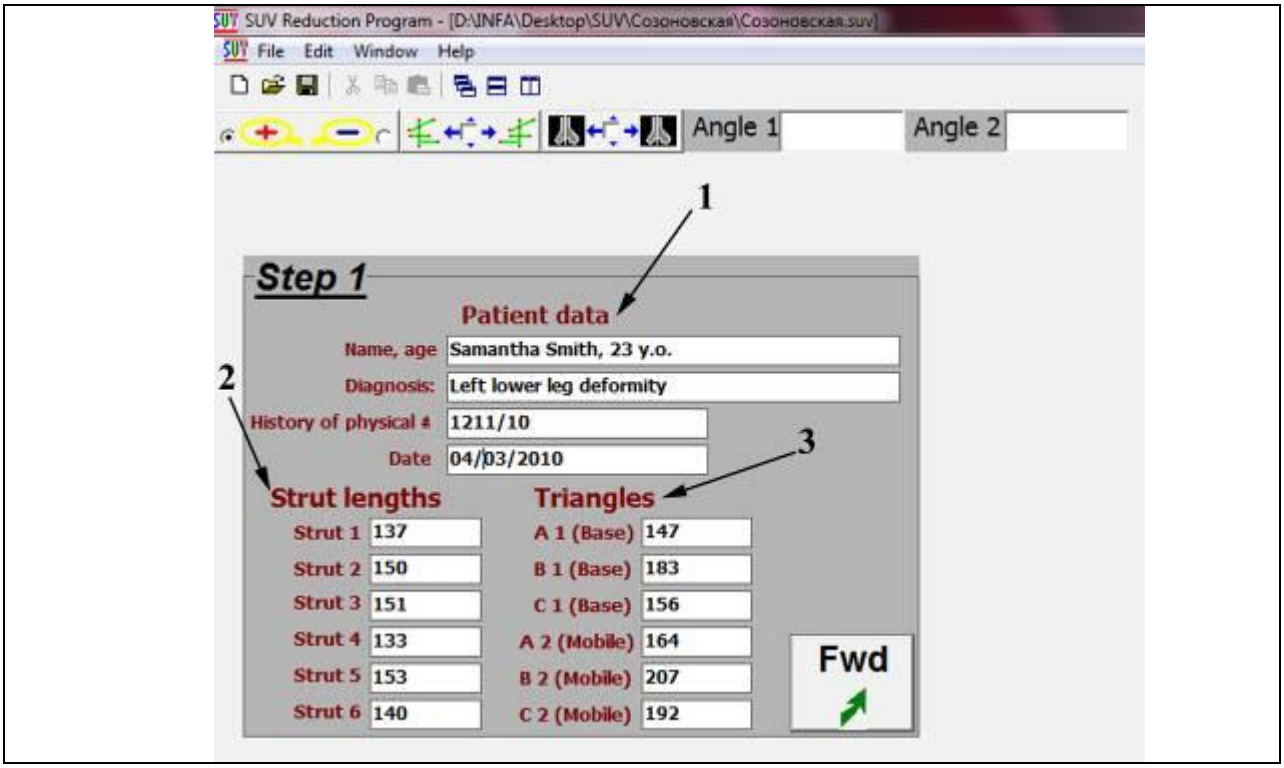


Fig. 27. Data input during step 1, where: 1 – patient data, 2 – strut lengths 3 – triangle side lengths

Шаг 2. Loading of AP roentgenogram

A movable panel appears with the button of AP roentgenogram loading: «AP view» (Fig. 28).

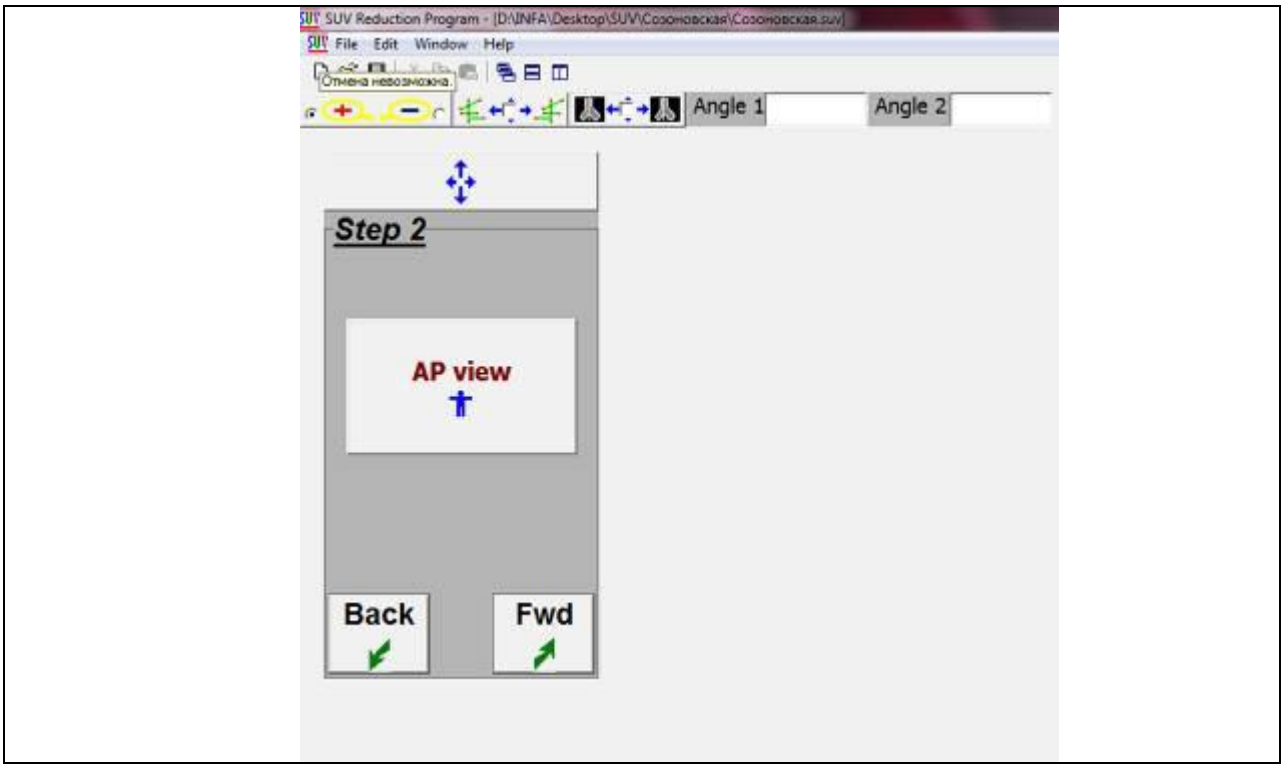


Fig. 28. Ortho-SUV program window before Step 2 (loading of AP view) is performed

In order for the AP roentgenogram to be uploaded, press the button “AP view”. Drop out list appears. Using “browse” function, choose the previously prepared AP roentgenogram. It may be located in any folder on the local hard drive or Internet. Press the button “Open”. At this point

operator is brought back to Step 2. Notice that the AP view itself *does not appear*. Press "forward' and move to the next step.

Step 3 Loading of the lateral (profile) roentgenogram

To load lateral digital roentgenogram, press the button «Lateral» (Fig. 29). Drop out list appears. By browsing through local files or those in the Internet, find previously prepared lateral roentgenogram. Press the «Open» button. Two radiographic images will appear in the document window: AP view to the left and the lateral view to the right (Fig. 30).

After these two views appear, press «Forward» and move to the next step.

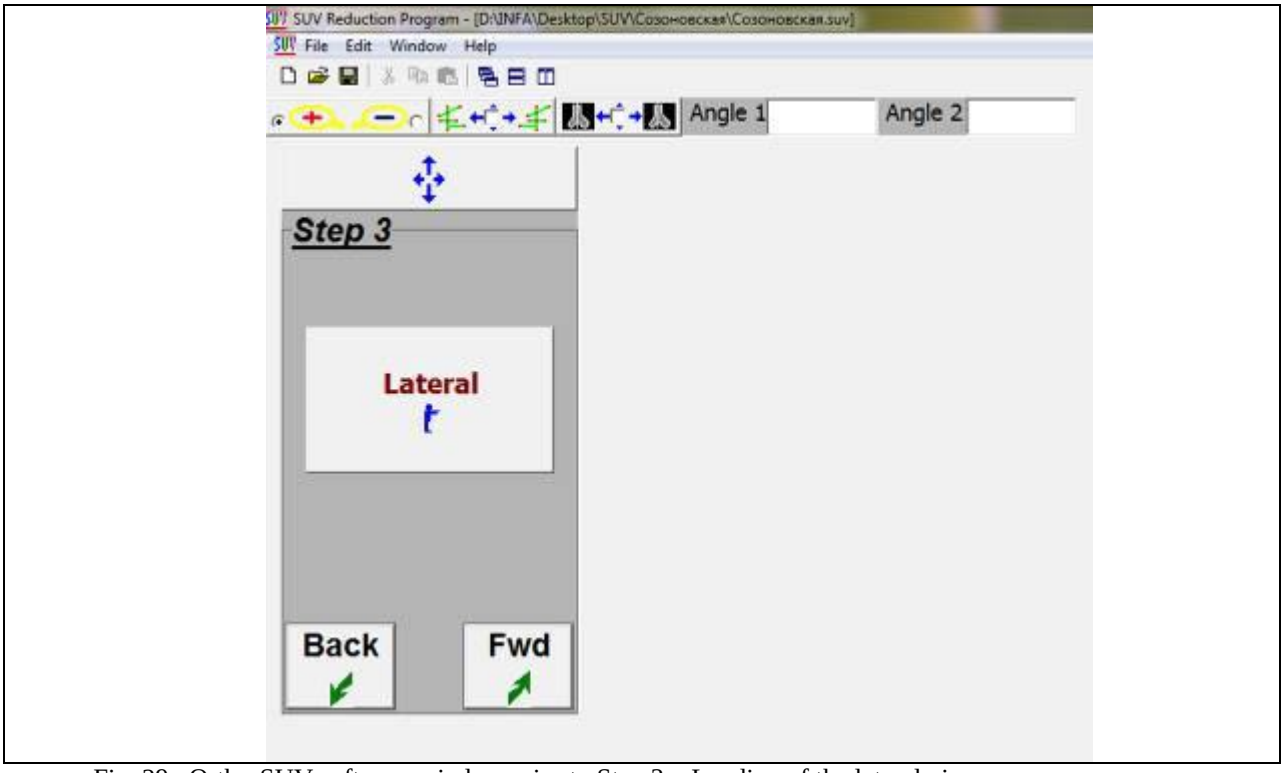


Fig. 29. Ortho-SUV software window prior to Step 3: «Loading of the lateral view»

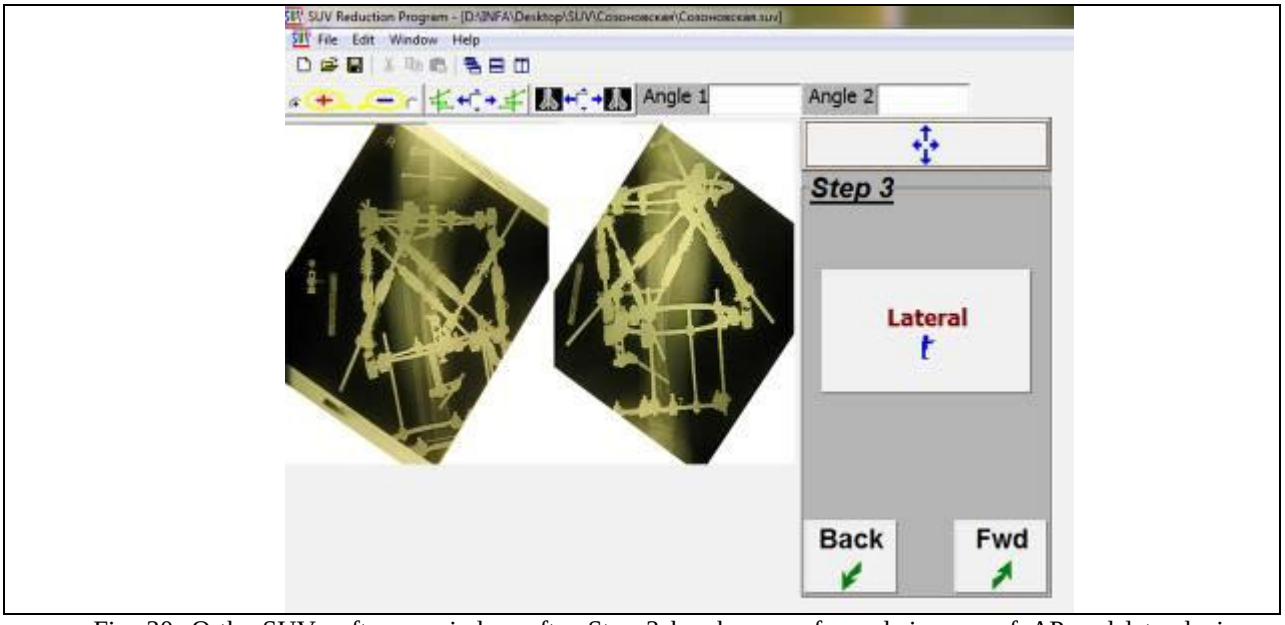


Fig. 30. Ortho-SUV software window after Step 3 has been performed: images of AP and lateral views appeared

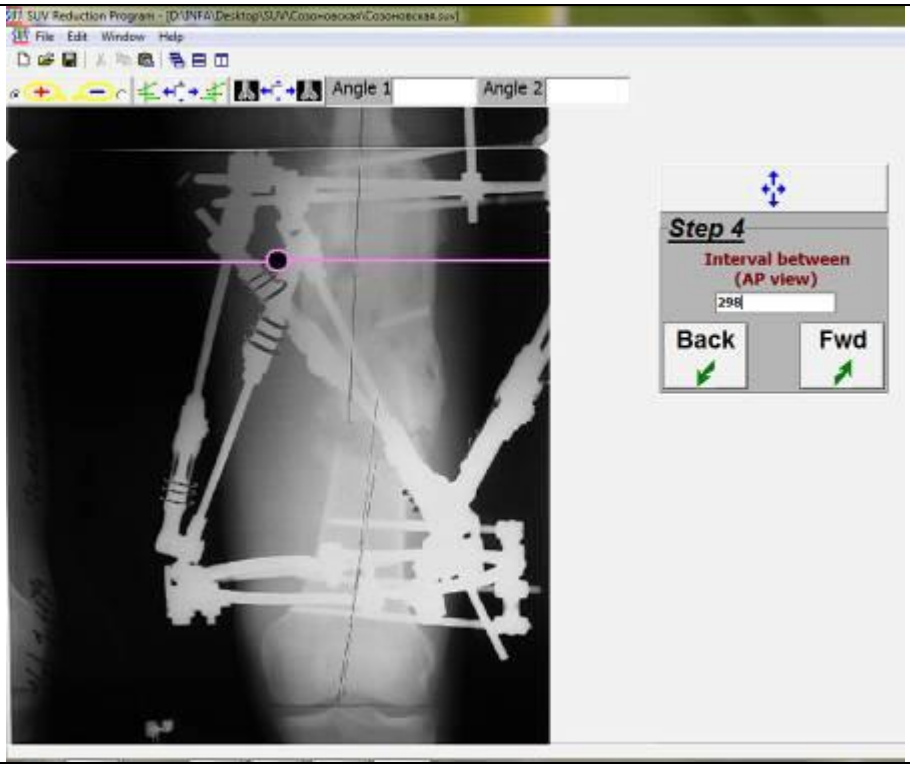
Step 4 Scaling of AP view

There is a special tool available in the program called conditionally a «ruler» (Fig. 31, 32). In order to scale an AP view, use this ruler, to measure off on the image a so called "known interval" – that is, a segment or interval with its length known to operator. This "interval with its length known" may be just any section on the image to the operator's choice. Extreme points of the «ruler» are set at the levels of extreme points of this interval. By marking extreme points of this "interval between", its length is measured off. With analog images as original source, an option for this interval might be length or width of the roentgenogram itself (Fig. 31). When it is digital images that are intended for scaling, an object of known length (i.e. a radiopaque ruler) might be placed within the image field on the top of X-ray table prior to the roentgenogram to be taken. Then "interval between" the extreme points of this object serves as a segment with its length known (fig 32).

NB! Scaling will be more precise, if interval between extreme points of the "segment with its length known" constituting not less than 80 мм.

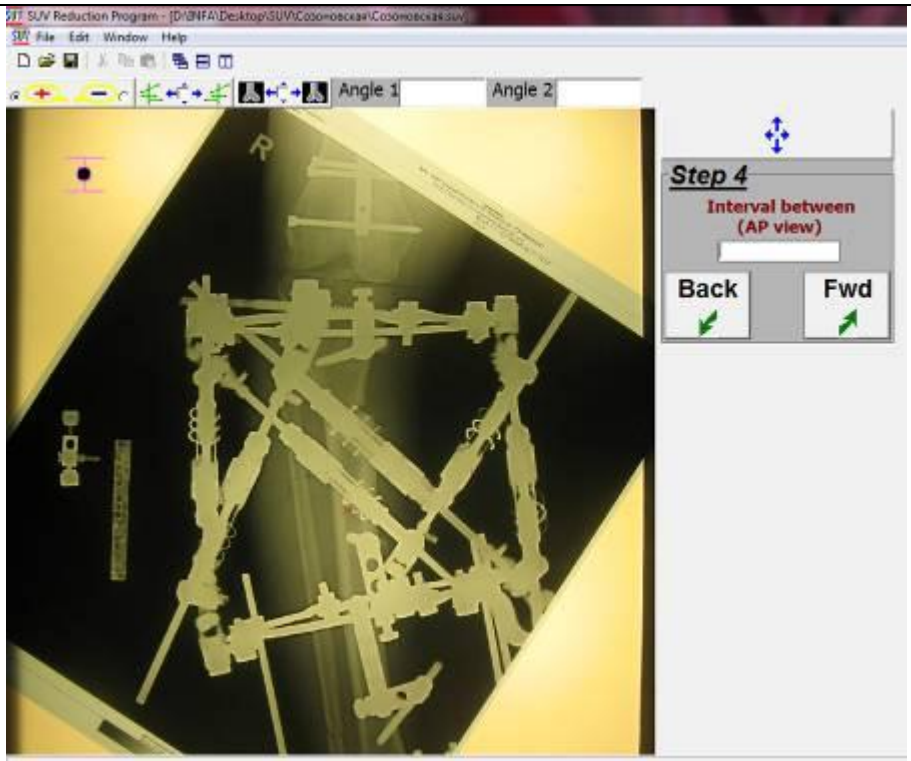
To move the "ruler", put the mouse cursor directly upon the center of the "ruler" (visible as a small circle), and, keeping the left mouse button pressed, move "ruler" around the display. To shorten "ruler" or lengthen it, put the mouse cursor directly upon one of its extreme points and drag, while keeping the left mouse button pressed. Having set length and position of the "ruler", fill in the field "Interval between" (AP view) by typing in the length of known interval in mm (Fig. 31) and press the "Forward" button to move to the next step.

a

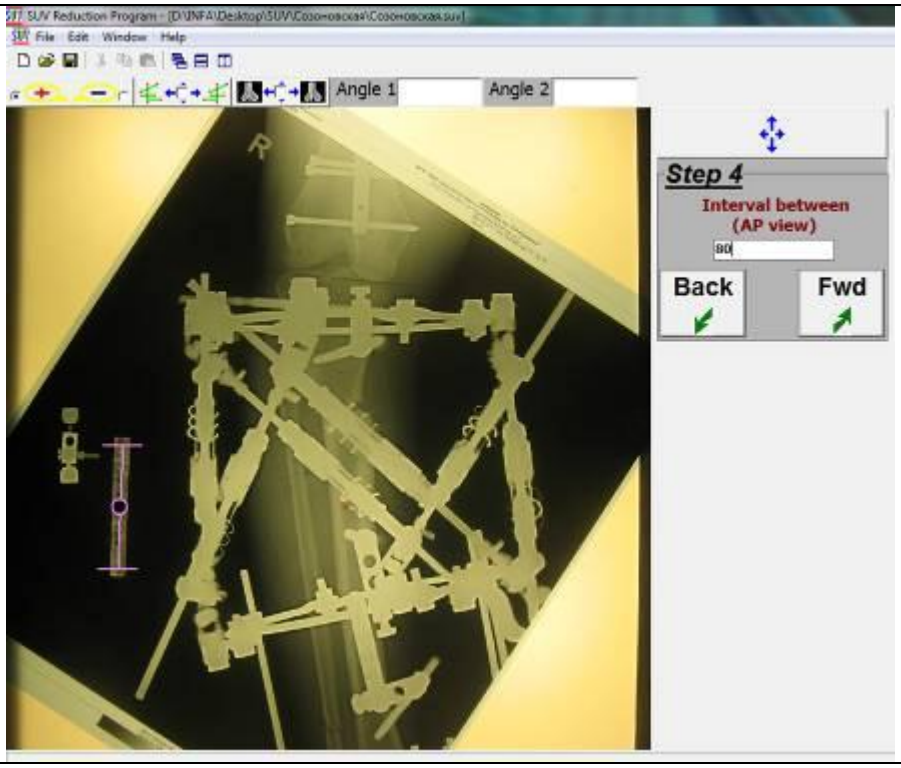


b

Fig. 31a,b. Ortho-SUV software window while performing Step 4: «Scaling of AP view» (with analog roentgenogram as initial source): a – prior to scaling; b – after scaling. Arrows point to scaling «rulers». As an interval with known length the width on the analog roentgenogram is used



a

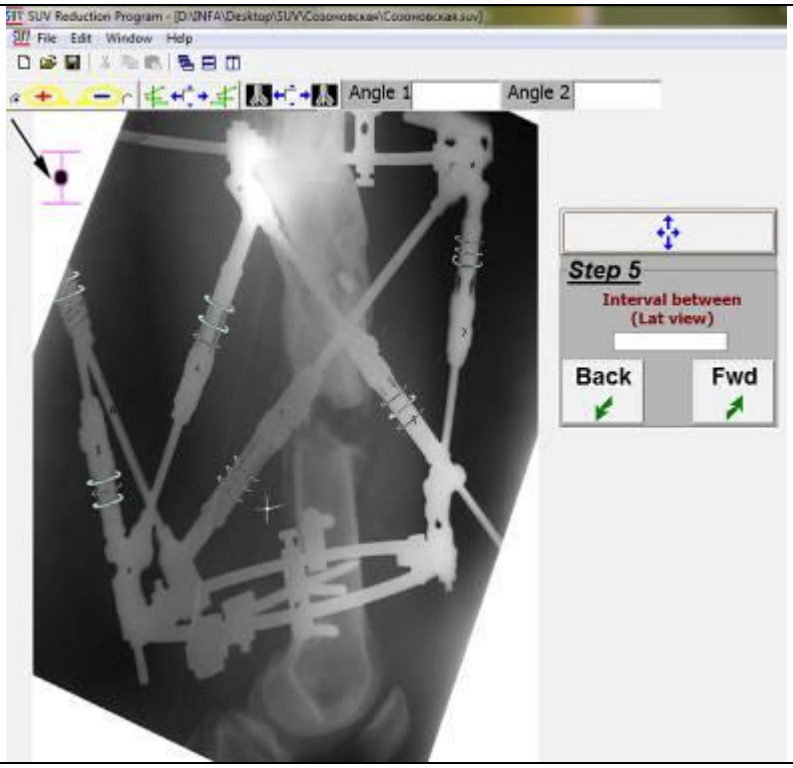


b

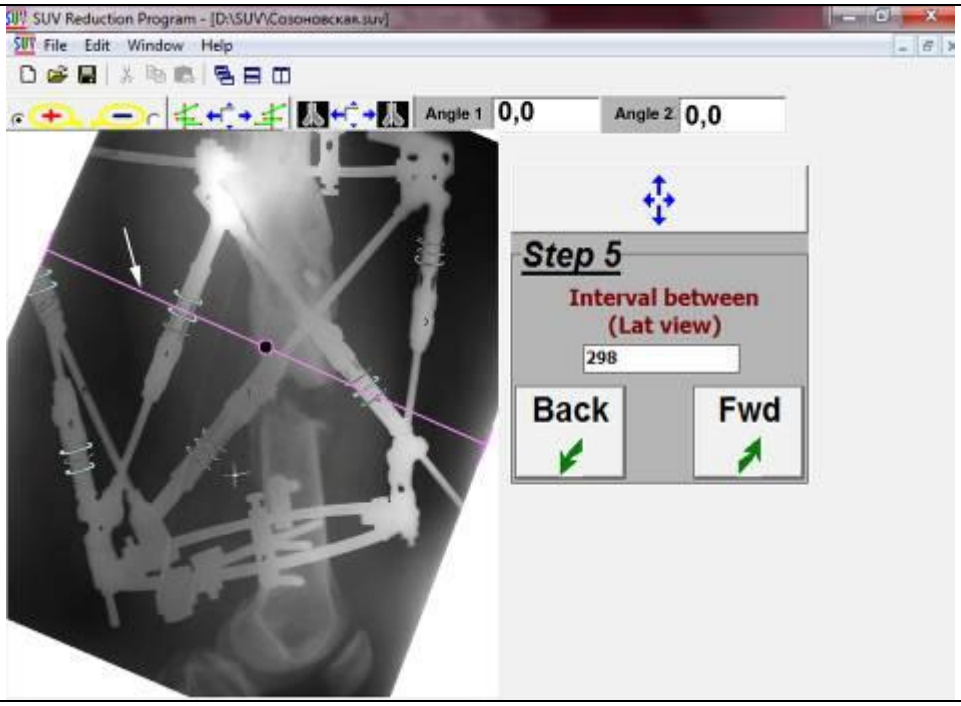
Fig. 32a,b. Ortho-SUV software window while performing Step 4: «Scaling of AP view» (with digital roentgenogram as initial source): a – prior to scaling; b – after scaling. Arrows point to scaling «rulers». As an interval with its length known a radiopaque ruler is utilized

Step 5. Scaling of the lateral view

Lateral view scaling is implemented in the same way as scaling of AP view (Figs. 33 and 34). Press "Forward" to move to the next step.

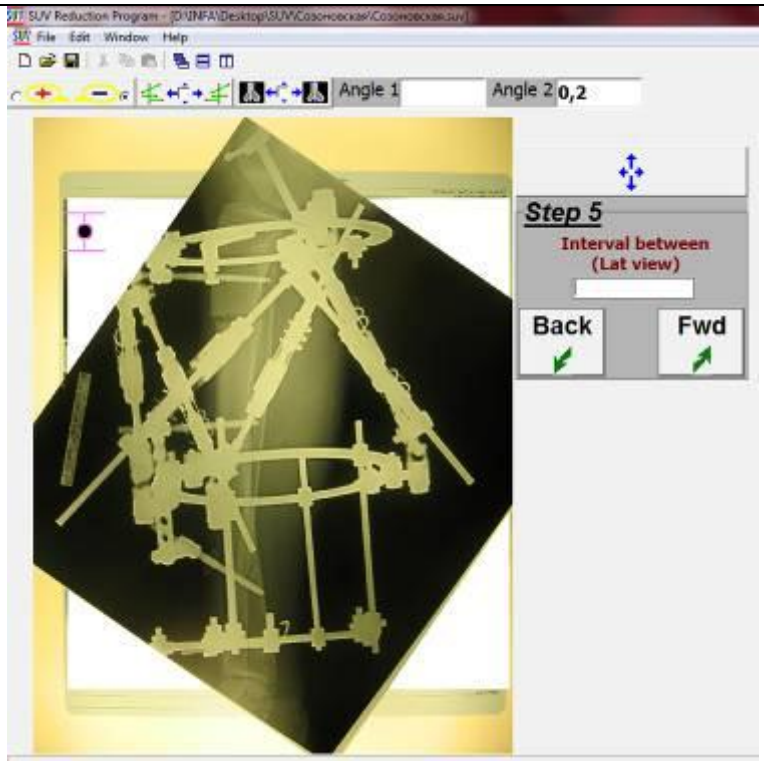


a

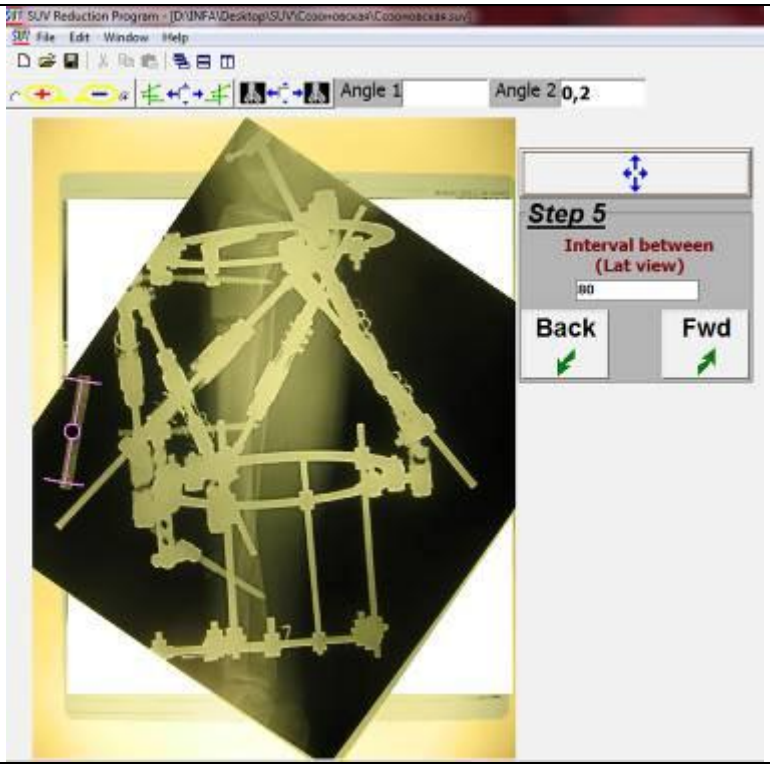


b

Fig. 33a,b. Ortho-SUV software window while performing Step 5: «Scaling of lateral view» (with analog roentgenogram as initial source): a – prior to scaling; b – after scaling. Arrows point to scaling «rulers». As an interval with known length the width on the analog roentgenogram is taken



a



b

Fig. 34a,b. Ortho-SUV software window while performing Step 5: «Scaling of lateral view» (with digital roentgenogram as initial source): a – prior to scaling; b – after scaling; Arrows point to scaling «rulers». As an interval with known length the segment between extreme points of a radiopaque ruler is used

Step 6 Filling in focal distance and beam center; indicating strut and joint projections on AP view

Type in the value of *focal distance* for AP view – distance between anode of X-ray tube and a plate-holder - in the field «Focal distance (AP view)». Additionally, indicate the *X-ray beam center* - by marker that looks as blue cross with red center - on the image of AP view (Fig. 35). Focal distance and location of beam center are defined in the process of X-ray examination. Detailed explanations are to be found in part 5.2 (Fig. 22).

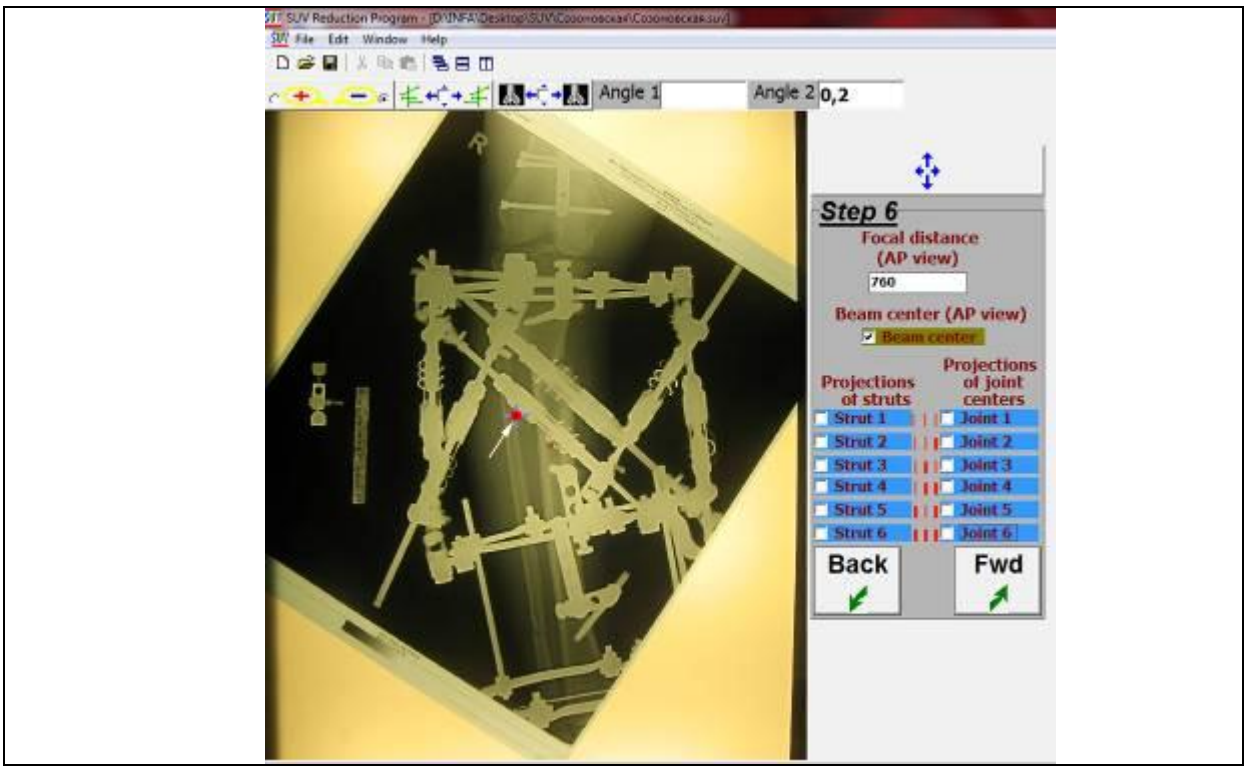


Fig. 35. Ortho-SUV software window in the process of performing Step 6. Focal distance value has been typed in and the X-ray beam center has been marked. The arrow points to the marker of beam center

Next stage involves marking of *strut and joint projections* on the image of AP view (Figs. 36 and 37).

NB! Strut and joint numbers indicated in program have to be the same as strut and joint numbers designated for the external fixation device calculations are made for. Arbitrary designation of the numbers is not allowed.

The simplest way to identify strut numbers on a roentgenogram involves using X-ray-positive strut number markers (section 5.2, Fig. 23).

In order to *mark a strut*, mouse click on the field of a strut. Then, keeping the left mouse button pressed, drag the line along the projection of this strut on the X-ray image (рис. 36a).

A joint marker consists of a line ending with a point and a circle with a point inside. *Joint number* is always the same as number of strut that "get into" it (Fig. 37). In order to *mark a joint*, mouse click on the field of the joint. Then put mouse cursor over the projection of this joint on the X-ray image and perform mouse-click by left button. Joint marker will be displayed (Fig. 36b). For accuracy, side (line) in this type of marker is to be aligned to the strut that gets into the joint as well as to the bolt that fixes the joint (Fig. 36c). To achieve this, put mouse cursor over the end of joint marker (visible as red dot). While keeping left mouse button pressed drag a line along the axis of bolt that fastens the joint. Then put mouse cursor over another red dot located inside of marker circle. Keeping the left mouse button pressed, drag a line along the axis of strut that gets into the joint. It does not matter which marker line corresponds to the strut and which marks the bolt. Strut marker and its respective joint marker have the same color. Strut and joint markers of different numbers are colored differently.

If joint field is checked, after its respective strut field had already been checked, the strut marker is completed with a line and a circle and becomes both strut and joint marker. And the opposite is true, too: when a strut field is checked when the respective joint field has been checked earlier, the joint marker is completed with a line and again, becomes both strut and joint marker. For example: joint №6 has already been marked on AP view. If field of strut №6 is

checked, the marker turns into a strut and joint marker at the same time and the line dragged along the strut axis becomes thicker (Fig. 36d).

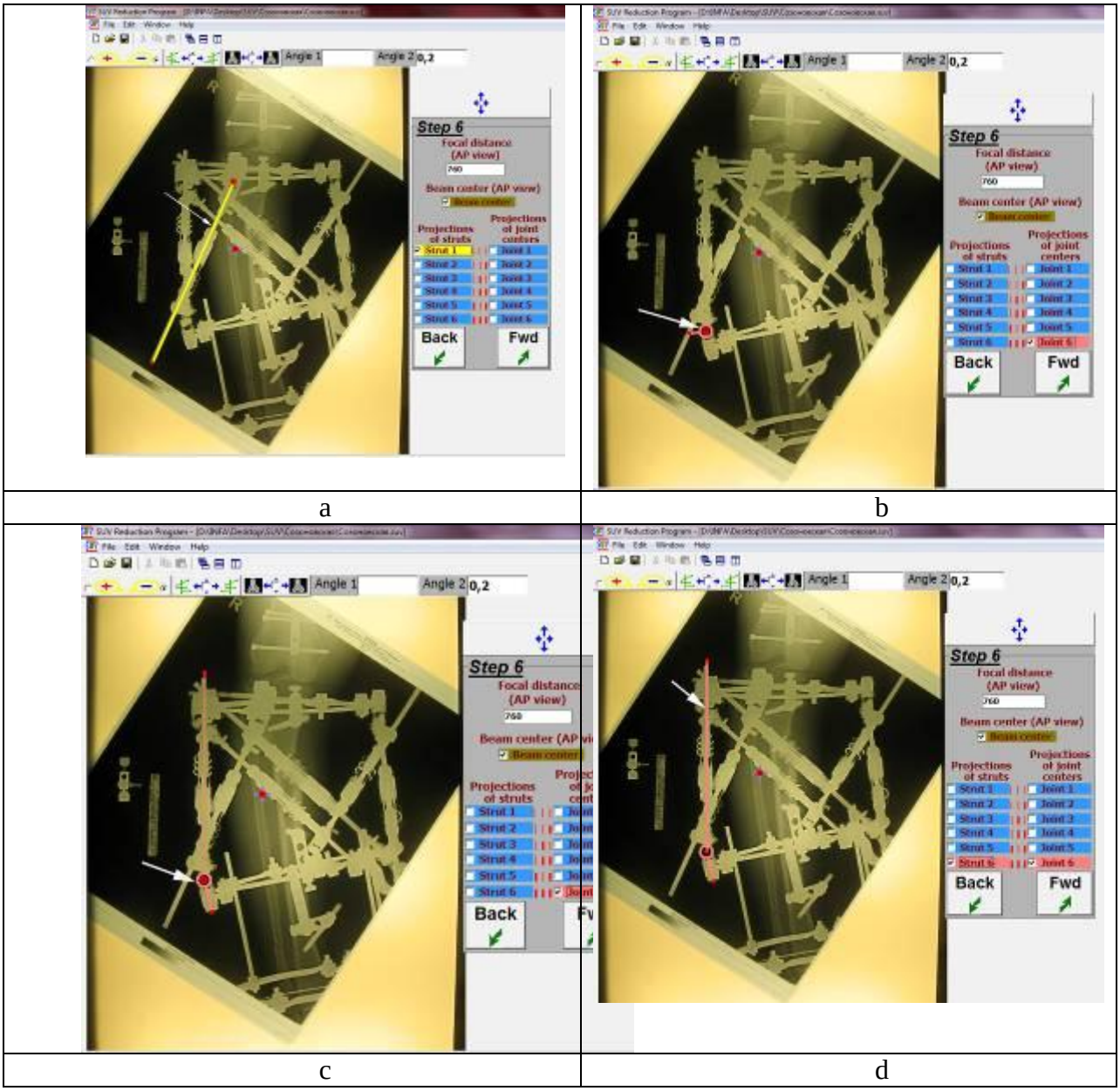


Fig. 36a-d. Ortho-SUV software window in the process of performing Step 6: "indicating of strut and joint projections". a – marker of strut №1; b – marker of joint №6 after its first appearance on the screen ; c – marker of joint №6 after it has been aligned to the bolt and the strut; d – appearance of a strut marker in the presence of earlier marked joint with the same number. Arrow point to the marker of joint №5

NB! For the program to function it usually suffices to indicate 3 struts and one joint - with the joint number differing from numbers of struts that have been marked (Fig. 37). If views are not orthogonal, that is, are angular to one another, all visible struts and joints must be indicated.

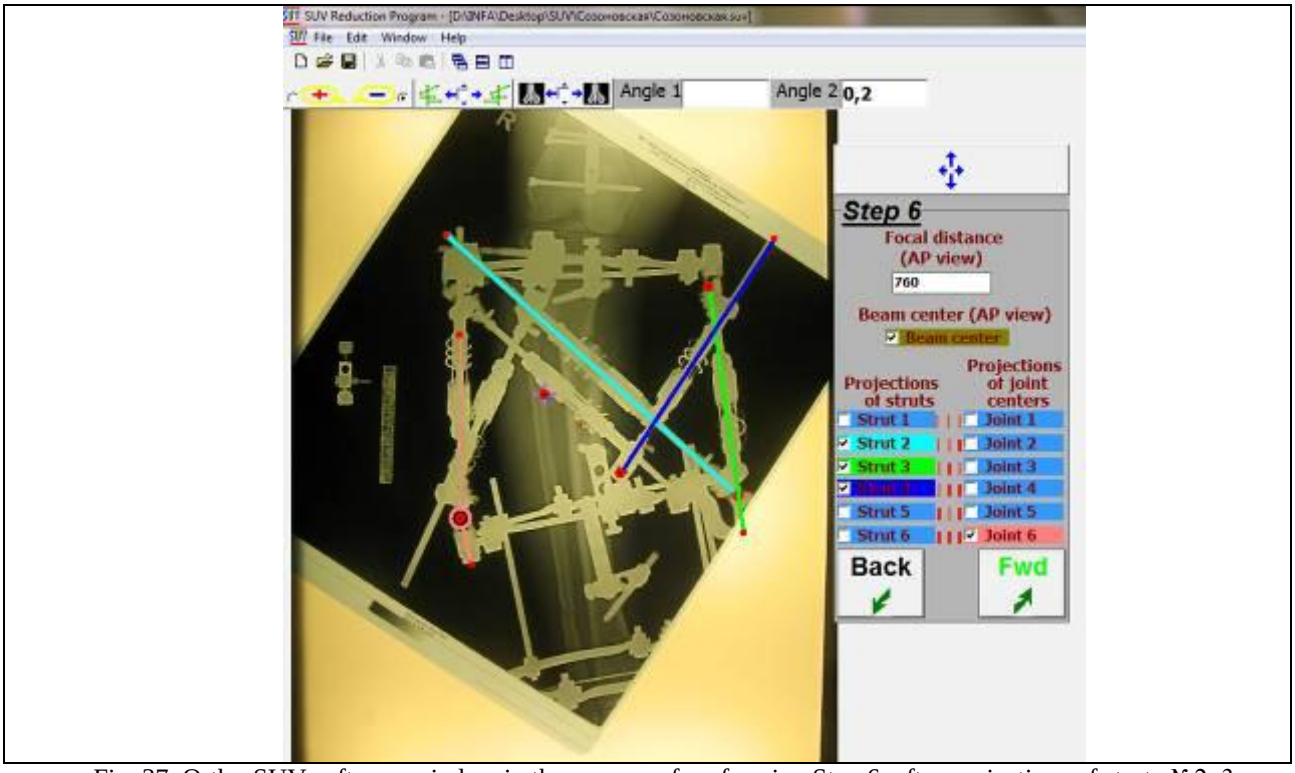


Fig. 37. Ortho-SUV software window in the process of performing Step 6: after projections of struts №2, 3 and 4 and joint №6 were indicated on AP view

As soon as the program gets enough information to continue, the "Forward" sign gets green and move to the next step becomes possible.

Step 7 Indicating focal distance and beam center; indicating strut and joint projections on the lateral view

This step (Figs. 38 - 40) is performed similarly to how step 6 is performed. It is necessary to emphasize, that numbers assigned to strut and joints in the program have to correspond to those in the frame calculations are being made for. Arbitrary designation of numbers is not allowed.

As a rule, for the program to work successfully it suffices to indicate 3 struts and one joint, with the joint numbered differently from the struts that are indicated. Struts and joints indicated on AP and lateral roentgenograms might not coincide. In other words, AP view might feature one set of joints and struts indicated, while on the lateral view another set is present.

NB! If AP and lateral views are not orthogonal, that is, are at angle to one another, all visible struts and joints ought to be indicated.

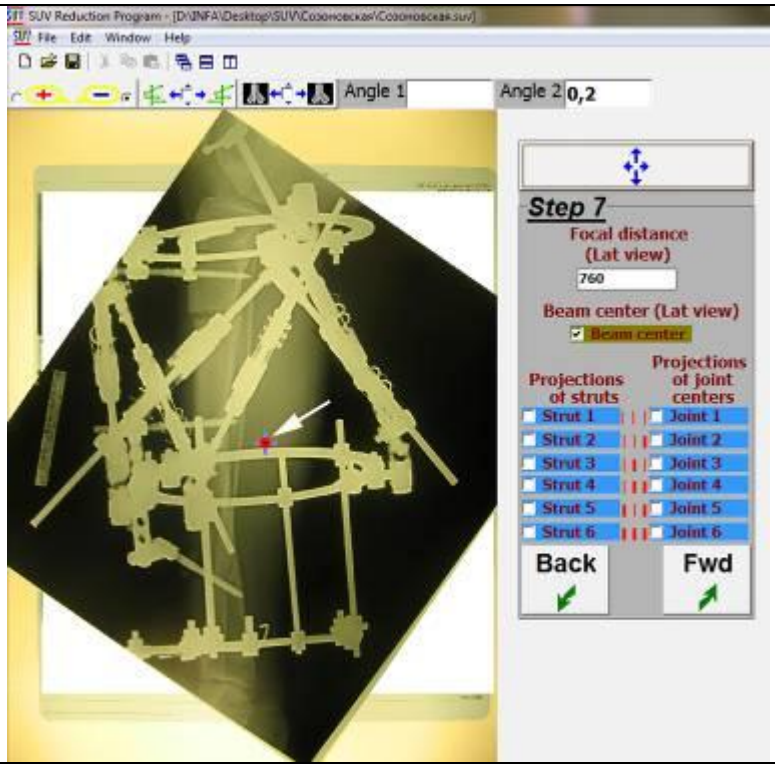
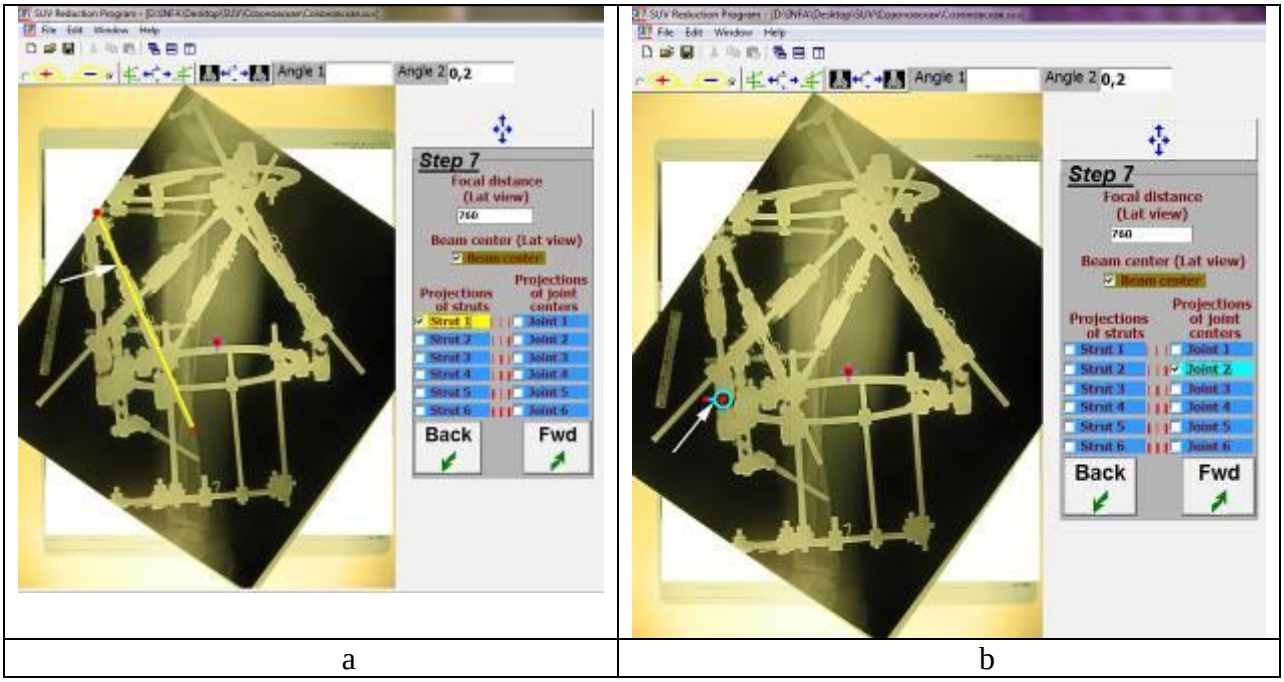
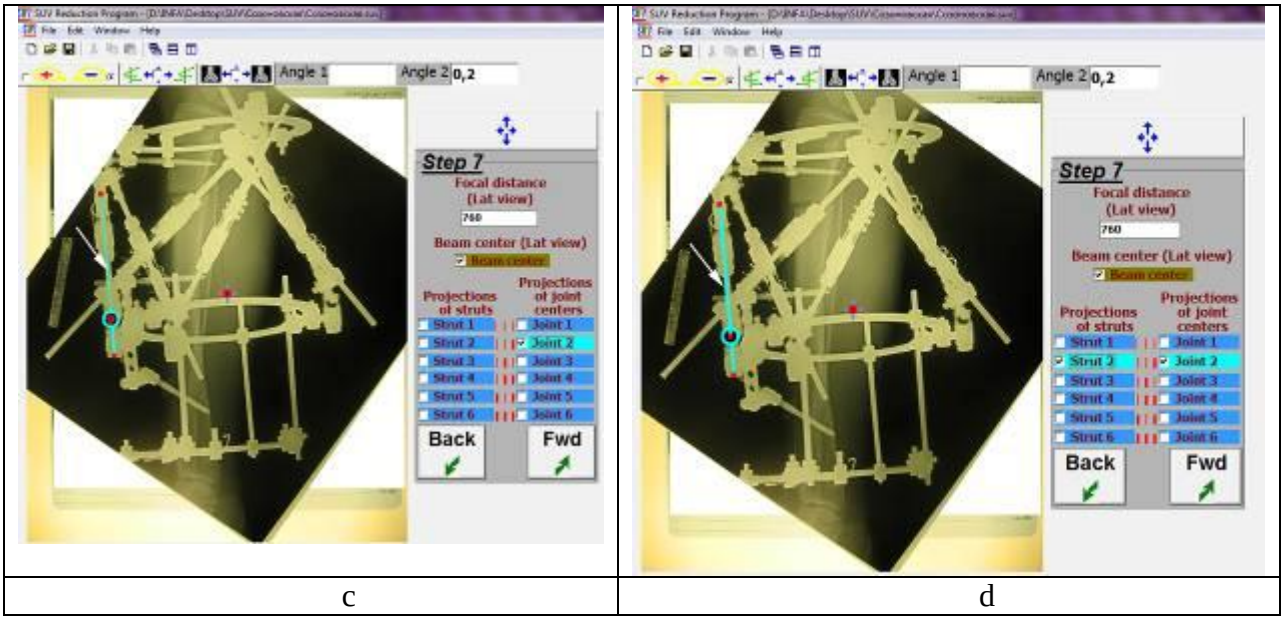


Fig. 38. Ortho-SUV software window in the process of performing Step 6 after focal distance has been typed in and the beam center indicated on the AP view. The arrow points to the beam center marker.



a b



c d

Fig. 39a-d. Ortho-SUV software window in the process of performing Step 7: indicating of strut and joint projections. a – marker of strut №1; b – marker of joint №2 upon its first display on the screen; c – marker of joint №2 after it has been aligned to the bolt and the strut; d – appearance of a strut marker in the presence of earlier marked joint with the same number. Arrows point to the marker of joint №2

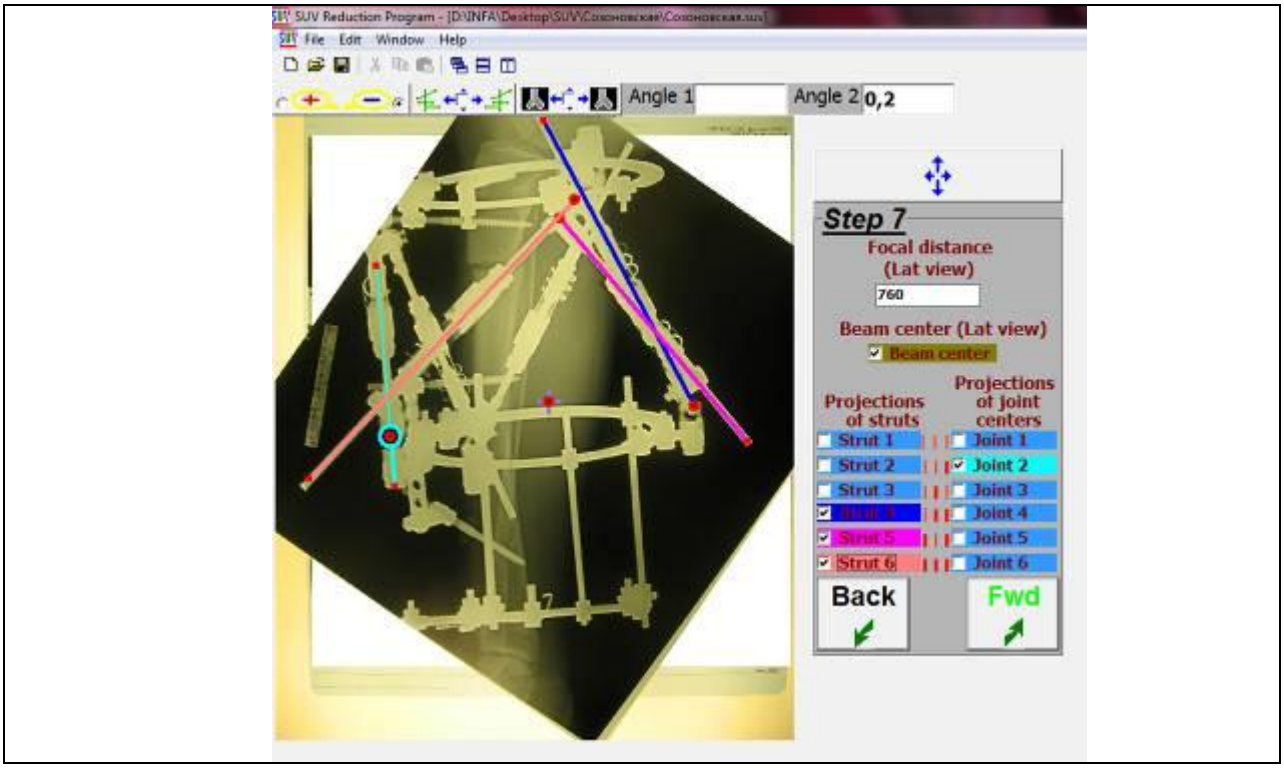


Fig. 40. Ortho-SUV software window in the process of performing Step 7, after projections of struts №4, 5 and 6, as well as of joint №2 have been indicated on the AP view

As soon as the program gets enough information to continue, the "Forward" button gets green and one can move to the following step.

After the "Forward" button has been pressed, the program processes all the data fed into it and comes out with digital frame model where length and position of strut projections have been calculated for both AP and lateral views. It takes, depending on speed of the computer, 10 seconds to 2 minutes.

After the calculation is finished, red lines will appear on both images: 6 lines on the AP view and 6 lines on the lateral view. These lines have to exactly match the projections of all strut axes. Permissible deviation is limited by a strut width as it shows on the image. *The congruency between red lines and struts serves as a criterion of correctness of data input* (Fig. 41). If this congruency is present for all the struts, press "Yes" and move to the next step.

NNB!! *If even a single red line does not match a strut as the latter shows on the screen*, press «No» to be taken back to step 7. It is necessary to get back to previous steps and consistently check data input. *Only when the congruency between all red lines and all strut projections is achieved, one may move to the next step!*

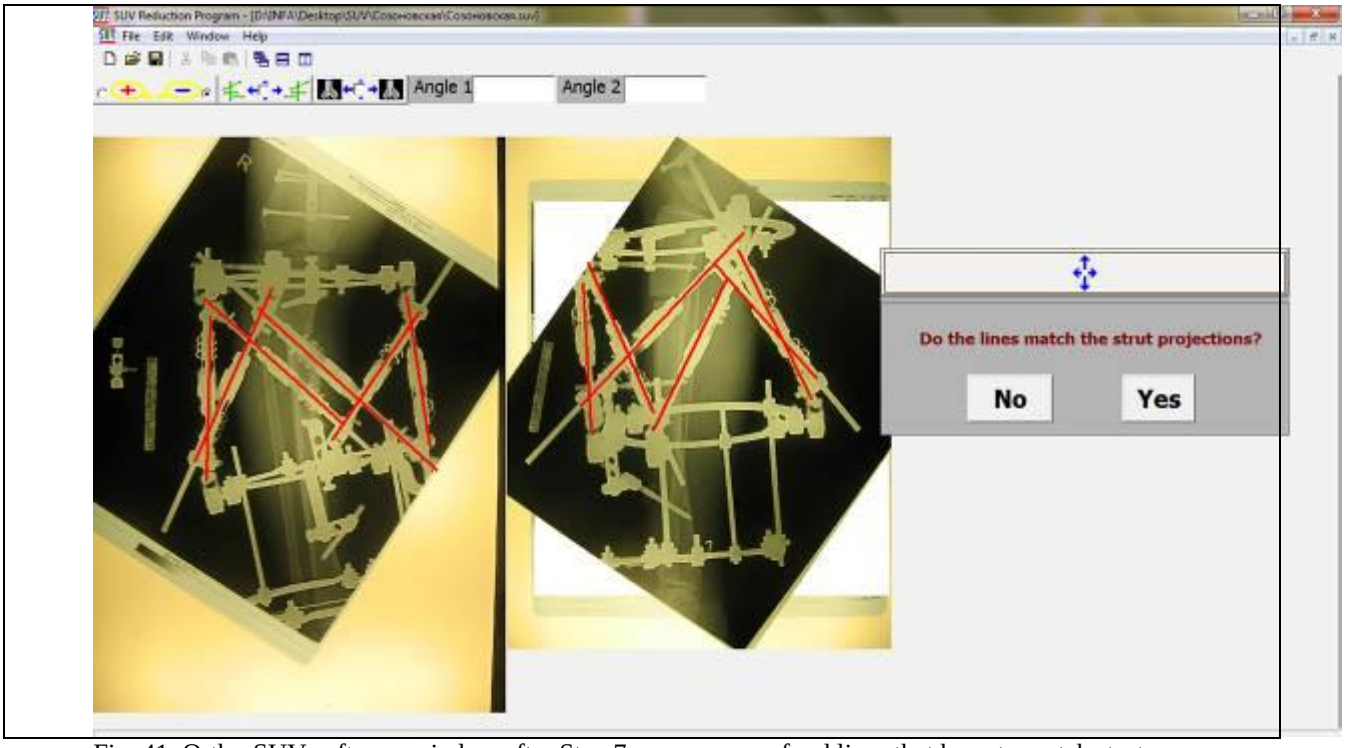


Fig. 41. Ortho-SUV software window after Step 7: appearance of red lines that have to match strut projections

Step 8 Marking of bone fragment axes

Special tools are used to mark axes of both base and mobile bone fragments – *bone-fragment markers* ("trees"). Base fragment marker is colored green, and mobile fragment marker is violet: "green tree" and "violet tree".

Fragment markers consist of the following elements (Fig. 42):

- axis line (1);
- centering line (2);
- angle marker (3);
- line of the angle marker (4);
- superposition pointer (5);
- line of the superposition pointer (6).

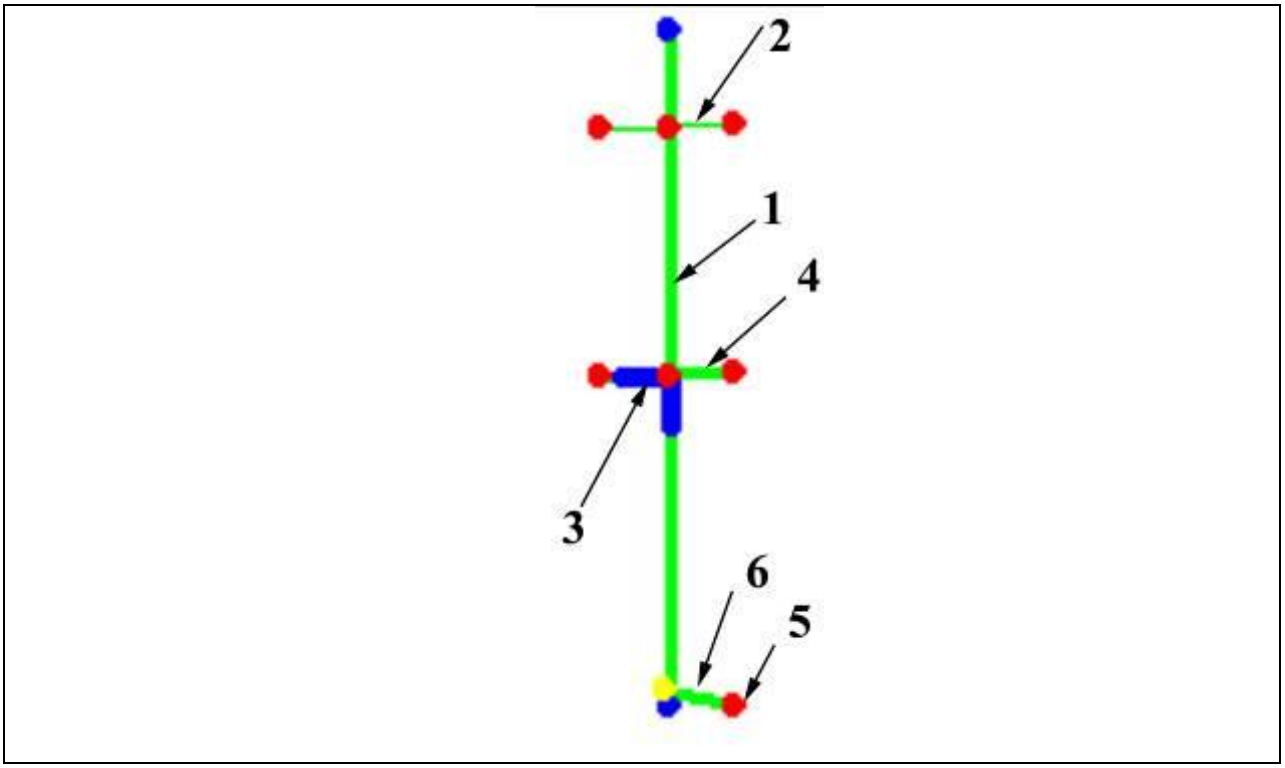


Fig. 42. Fragment marker in Ortho-SUV software (“tree”): 1 – axis line; 2 – centering line; 3 – angle marker; 4 – line of angle marker; 5 – superposition pointer; 6 – line of superposition pointer

Axis line (1) always divides centering line (2) and line of angle marker (4) into two equal parts. Angle marker (3) consists of two short blue lines coming out of crossing point between axis line and angle marker line. The first short line goes along axis line, the second one goes along angle marker line. Line of superposition pointer (6) connects superposition pointer (5) with axis line.

Axis lines of fragment markers must be set to match anatomical axes (middle-diaphyseal lines of bone fragments). An algorithm to achieve goes as following:

1. The field "Base fragment marker (AP view)" is ticked off. Mouse cursor is then brought to the distal portion of the base fragment, over its middle part. Press left mouse button and, keeping it in that way, drag the axis line of base fragment on the AP view *from bottom to top*. When the line is finished, it will be replaced by base fragment marker colored green (Fig. 43). If the position of base fragment marker is correct, line of superposition pointer will be its lowest part. If operator by mistake dragged the line not from bottom to top but vice versa, from top to bottom, line of superposition pointer will get wrong location, that is, at the very top of fragment marker. To correct this mistake, deselect the field “Base fragment marker” (AP view), put the mouse cursor over the image of AP view and press the left mouse button once. Then go through the algorithm again, this time dragging the line in due direction.

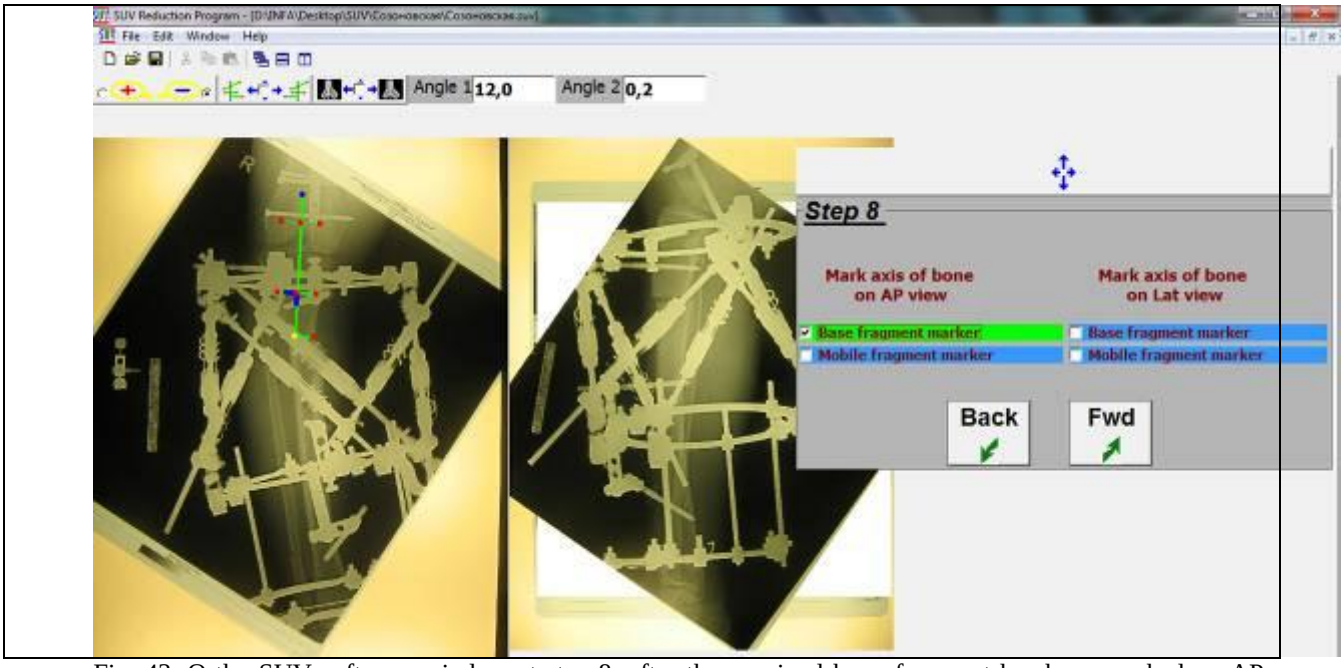


Fig. 43. Ortho-SUV software window at step 8, after the proximal bone fragment has been marked on AP view

In order to set the axis line of fragment marker in strict alignment with *anatomical axis of base bone fragment*, put mouse cursor over the end of centering line of angle marker and, while keeping left mouse button pressed, place this point on the cortical layer positioned to the left. In similar way, put the second extreme point of centering line of base bone fragment marker on the cortical layer positioned to the right. With the same technique, set extreme points of the centering line of angle marker on another level of the bone. As a result, anatomical axis of proximal bone fragment will be built on AP view (Fig. 44).

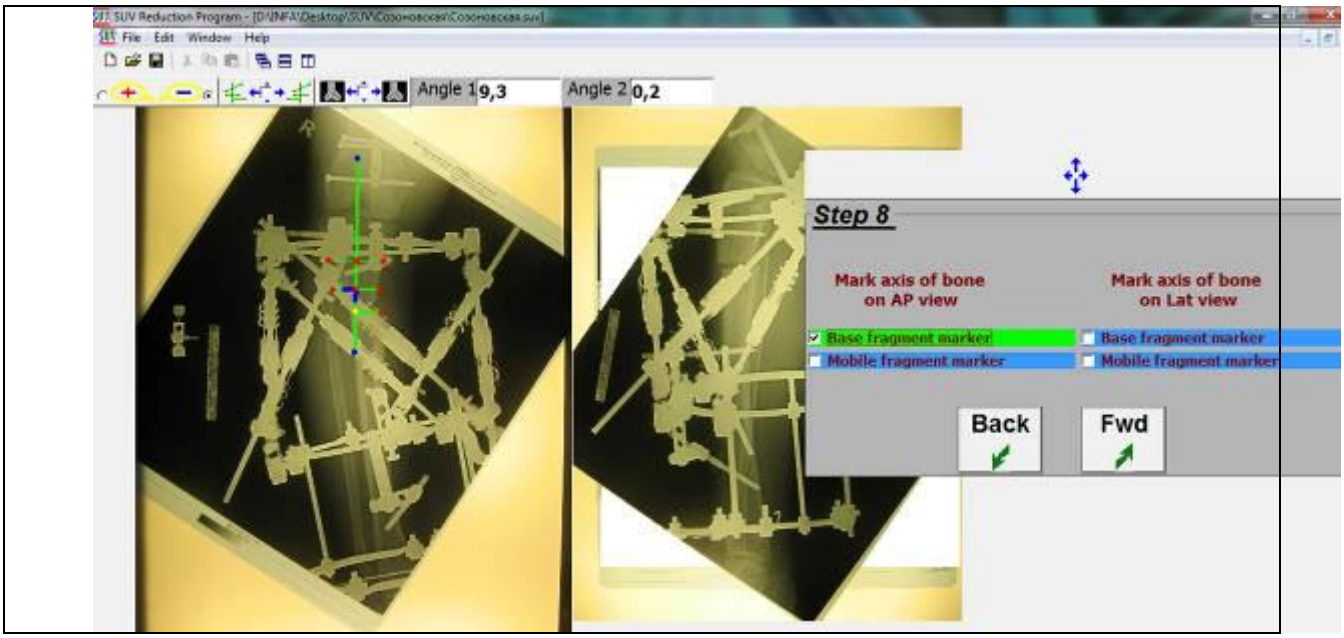


Fig. 44. Ortho-SUV software window while performing step 8, after the axis of proximal bone fragment has been built on AP view

2. The field "Mobile fragment marker (AP view)" is ticked off. Mouse cursor is then brought to the proximal portion of the mobile fragment, over its middle part. Press left mouse button and, keeping it that way, drag the axis line of distal fragment on the AP view from *top to*

bottom. When the line is finished, it will be replaced by mobile fragment marker colored violet. If the position of mobile fragment marker is correct, line of superposition pointer will be located at its highest point. If operator by mistake dragged the line not from top to bottom but vice versa, from bottom to top, line of superposition pointer will get wrong location, that is, at the very bottom of fragment marker. To correct this mistake, deselect the field “Base fragment marker” (AP view), put the mouse cursor over the image of AP view and press the left mouse button once. Then go through the algorithm again, this time dragging the line in the proper direction.

In order to set the axis line of fragment marker in strict alignment with *anatomical axis of mobile bone fragment*, put mouse cursor over the end of centering line of angle marker and, while keeping left mouse button pressed, set this point upon the cortical layer positioned to the left. In similar way, put the second extreme point of centering line of base bone fragment marker on the cortical layer positioned to the right. With the same technique, set extreme points of the centering line of angle marker on another level of the bone. As a result, anatomical axis of distal bone fragment will be built on AP view (Fig. 45).

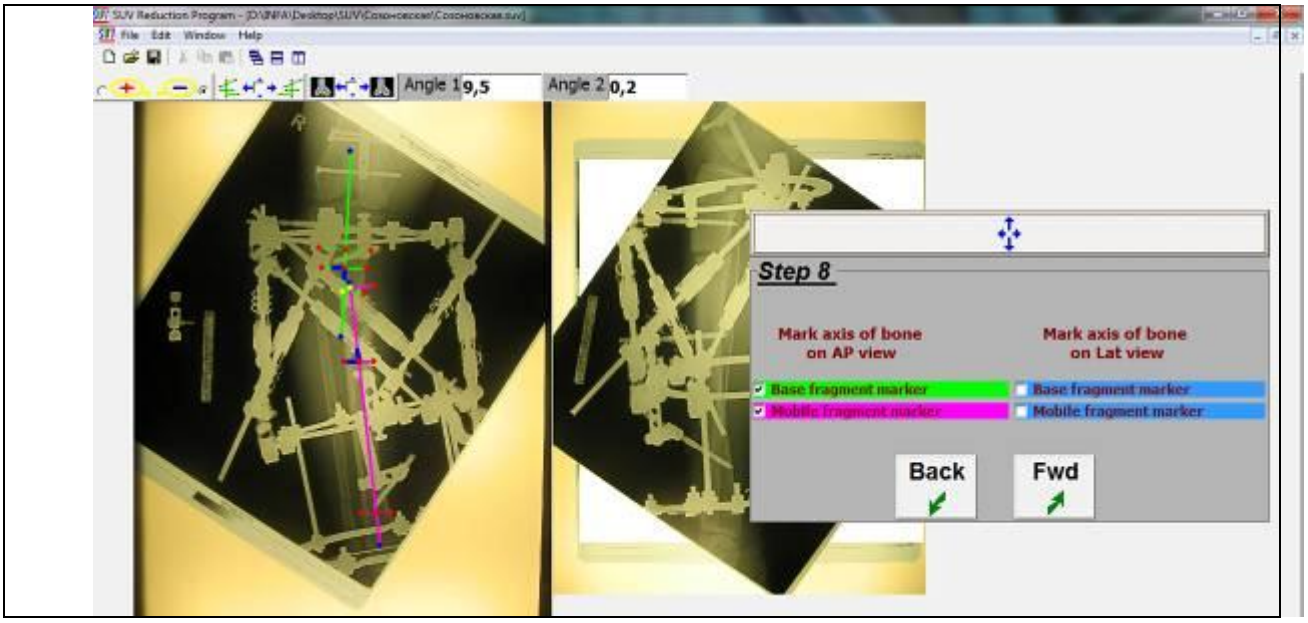


Fig. 45. Ortho-SUV software window while performing step 8, after the axes of both proximal and distal bone fragment have been built on AP view

3. Select the field "Base fragment marker" (Lateral view) by ticking it off. Axis line of base bone fragment on lateral view is defined similarly to how it has been done for the AP view. The line is dragged *from bottom to top* (Fig. 46).

Fig. 46. Document window of "Ortho-SUV" program while performing step 8, after the axis of proximal bone fragment has been defined on the lateral view

4. Select the field "Mobile fragment marker (Lat view)".

Axis line of mobile bone fragment on lateral view is defined similarly to how it has been done for the AP view. The line is dragged *from top to bottom*.

As a result, anatomical axis of both proximal and distal bone fragments are defined on AP and lateral views (Fig. 47). If bone fragment markers are not set, no further work with the program is possible.

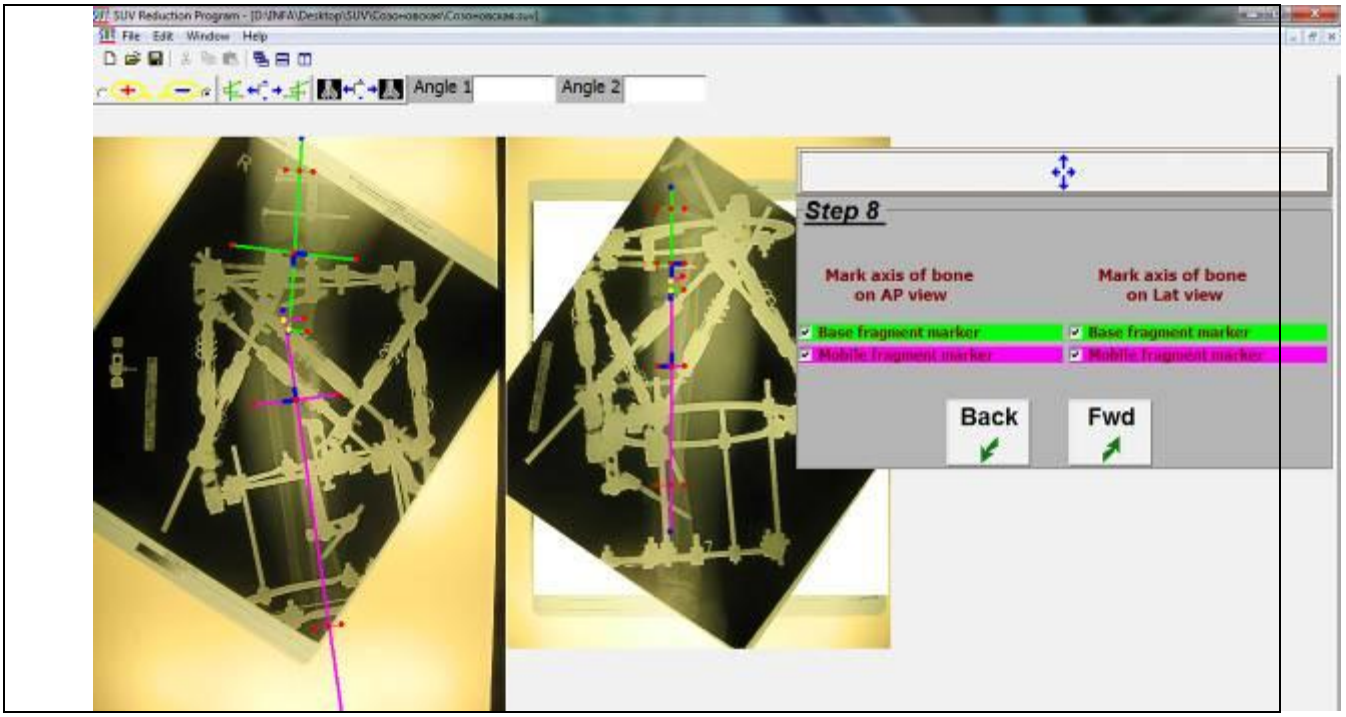
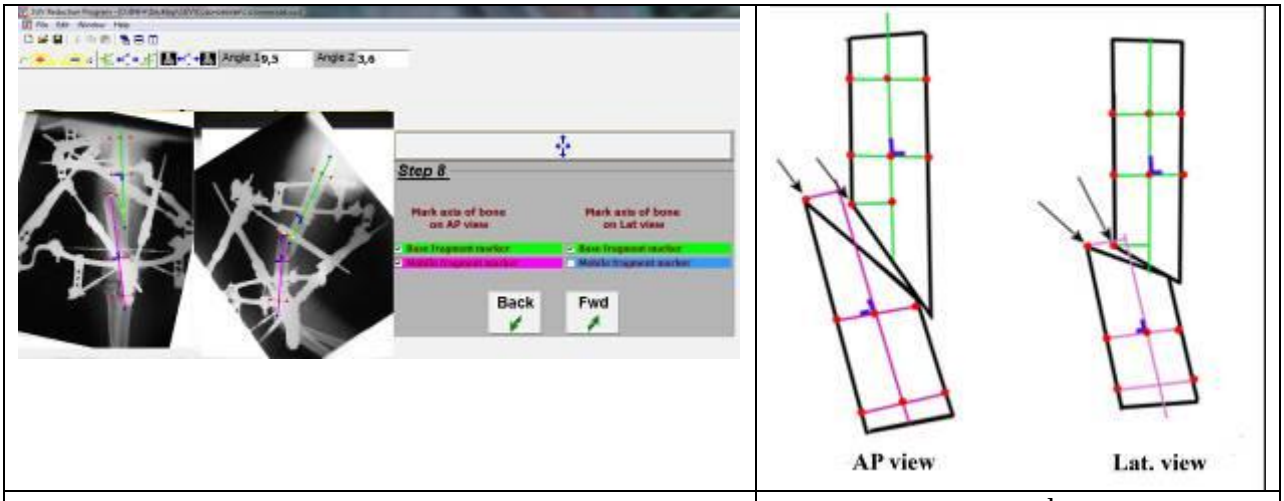


Рис. 47. Ortho-SUV software window while performing step 8 - after the axes of proximal and distal fragments have been defined on both AP and lateral views

5. Set the ***superposition pointers*** (Fig. 42-5). There are several different applications of those, depending upon the required effect:

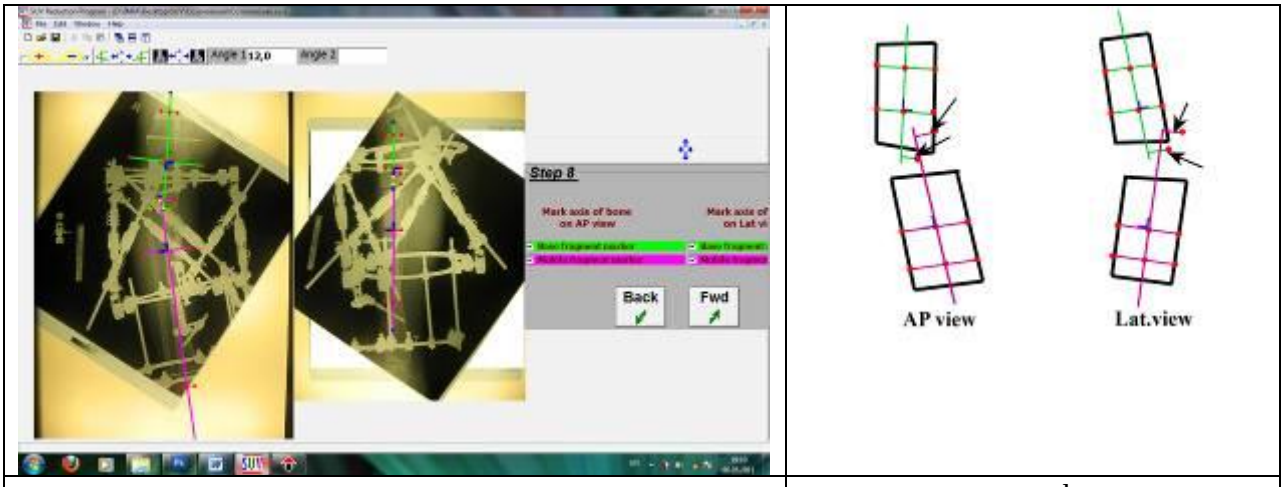
- To indicate points on proximal and distal fragments to be superposed. It is often the case for *non-comminuted fractures*, when it is not difficult to define points for superposition. In order to achieve this, the superposition pointer that "belongs" to the *base* bone fragment marker has to be set upon (user-defined) point on the base bone fragment. Put mouse cursor over the pointer, press the left button and, keeping it pressed, bring upon required point and then let go. Similarly, set the superposition pointer which is part of *mobile* fragment marker, upon the point on mobile fragment, intended for superposition (Fig. 48).



a b

Fig. 48a,b. Superposition pointers are set upon projection of the points on proximal and distal fragments, that have to be superposed for the fracture to be reduced: a – Ortho-SUV software window. b – scheme (the arrow indicating superposition points)

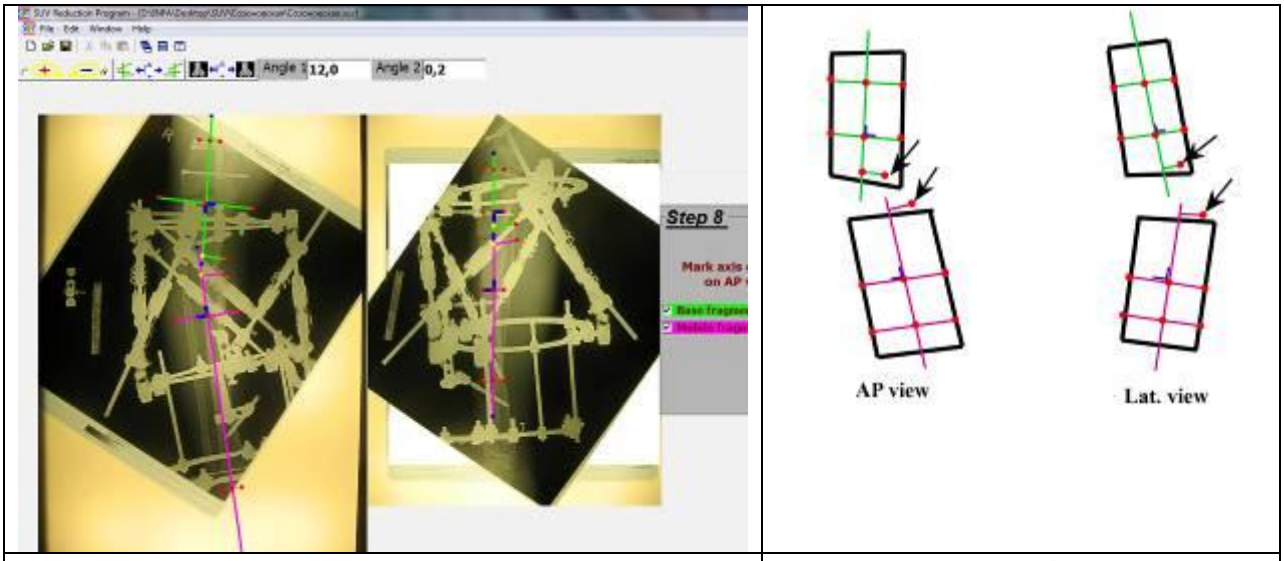
- Another application of superposition pointers involves situations, requiring axis displacement of mobile fragment: *«compression»* or *«distraction»*. When the superposition pointer, that "belongs" to base fragment marker, is set below the end of base fragment and (or) another pointer, of mobile fragment marker – is set above the end of mobile fragment, the program will calculate *distraction* (Fig. 49).



a b

Fig. 49a,b. Ortho-SUV software window: setting the lines of superposition pointers to achieve distancing bone fragments from one another ("distraction"): a – document window; b – scheme (arrows indicate lines of superposition pointers)

In order to assign compression (bringing the bone fragments together), the pointer of base fragment marker is set proximally to the level of base fragment end, and the pointer of mobile fragment marker is set distal to the end of mobile bone fragment (Fig. 50).



a b

Fig. 50a,b. Ortho-SUV software window: setting the lines of superposition pointers to achieve the bringing of bone fragments together («compression»): а – program window; б – scheme (arrows indicate the pointer lines)

To *move the superposition pointer*, get the mouse cursor over it and, keeping the left mouse button pressed, move the pointer along the axis line to the required distance. Technique for measuring and assigning the necessary compression or distraction values is expounded while describing step 11.

NB! For step 8, the obligatory part is setting the bone fragment markers. The rest of manipulations (setting the markers in alignment with bone fragments, assigning the axis displacement of bone fragments, marking the superposition points) might be carried out or fine-tuned at step 11.

Program also possesses the capability to achieve such a positioning of axis lines that it corresponds with positioning of ***mechanical axes*** of bone fragments, thus, enabling deformity correction and fracture reduction using mechanical axes at planning stage. Detailed explanation is to be found in description of step 11.

Having set fragment markers, press "Forward".

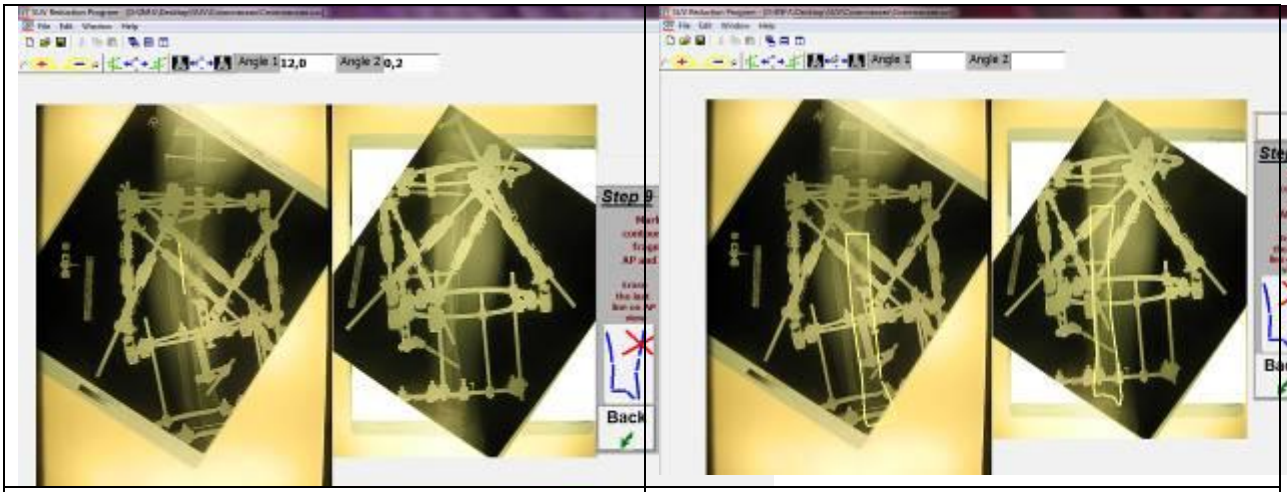
Step 9. Drawing bone contours

Performing this step the contour of the mobile bone fragment is outlined with yellow solid or dash line on the anterior and lateral views (Fig. 51). To do this the mouse cursor is pointed over the surface of the cortex layer of the mobile bone fragment. Left-click and holding the mouse button draw a line. Drawing the necessary series of lines the bone fragment is outlined. If the last fragment of the line is drawn incorrectly use the button called “Erase the last line”.

Having drawn bone contours on the anterior and lateral views, click the “Fwd” button.

NB! Lengths of the bone contours on the anterior and lateral views must be equal. There can be dots or lines drawn accidentally by the yellow marker beyond the bone contours, when

trying to move the bone contours in the window, and the special program option is not used. But the program interprets these dots and lines as well as the outlined contour of the distal fragment as a single picture. That is why the next step will be impossible to perform because the program will not consider the bone contours medial line to be correct. All accidental dots and lines must be erased.



a b

Fig. 51a,b. Ortho-SUV software window after completion of Step 9: a – the line is drawn o the anterior view; b – the mobile fragment on the anterior and lateral views is outlined with yellow line.

Step 10. Marking anatomical axes of the mobile fragment on A-P and lateral views

To mark the anatomical axis the mouse cursor is located in the center of the bone contours of the mobile bone fragment several centimeters higher over its proximal end. Holding the left button, draw a solid line along the center of the bone contour of the mobile bone fragment (the line can consist from several segments but no intervals must be between them; it should be a single straight, curved or zigzag line). If the bone has several curvatures the line must outline all of them. The medial lines on the bone contours are marked both on the anterior and the lateral views (Fig. 52).

NB! The anatomical axes of mobile fragment must exceed the proximal and distal ends of the bone contour of the mobile bone fragment by several centimeters. If the X-ray is short and it is impossible to draw the medial line above the distal end of the bone contour one must return to Step 9, remove the bone contour and make a new one which is to be shorter than the initial bone contour.

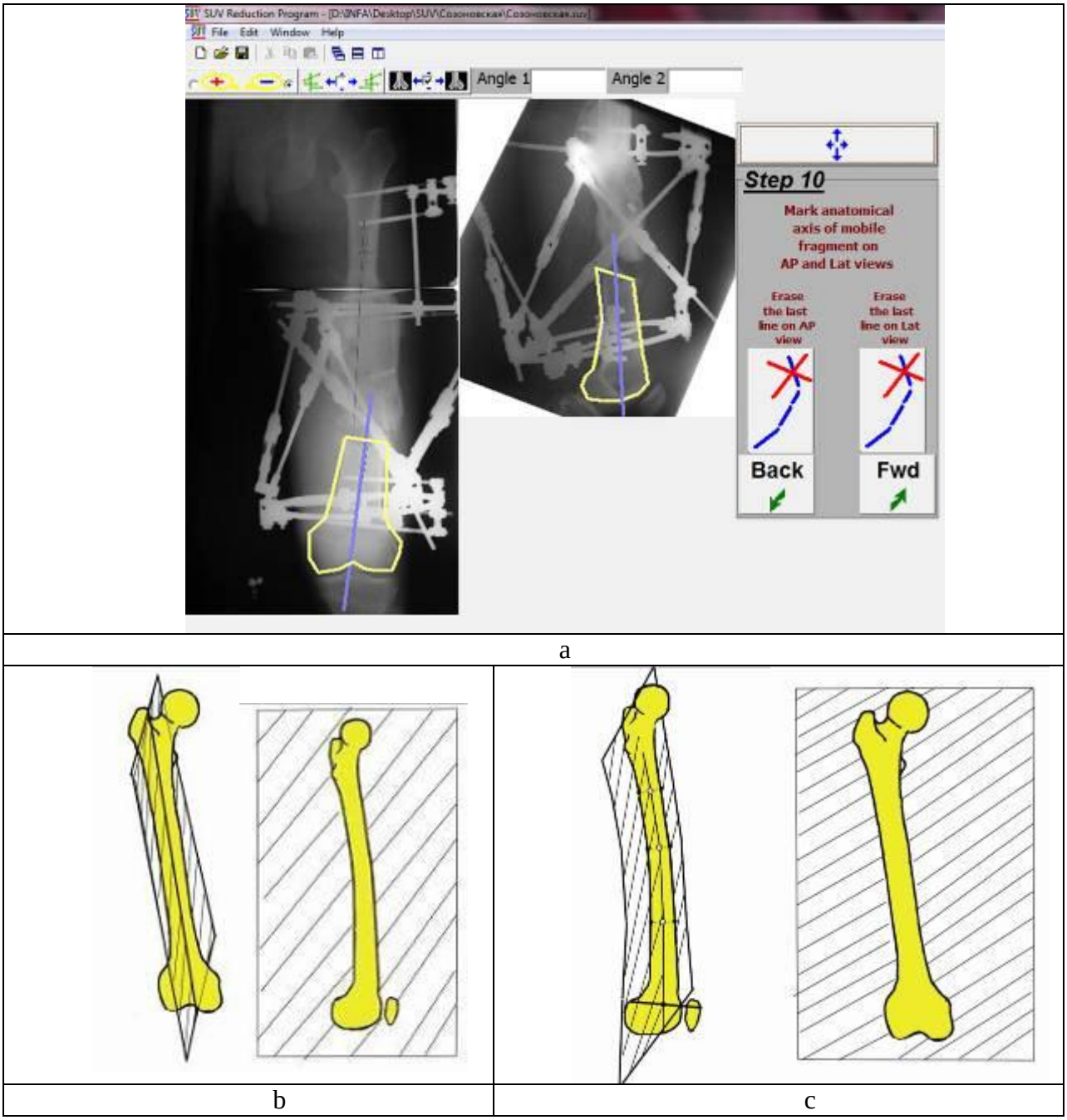


Fig. 52 a-c. Ortho-SUV program window after completion of Step 10: on the anterior and lateral views the anatomical axes of mobile fragment are marked with blue lines (a) and explanatory schemes (b,c)

Step 11. Choosing the mode of the bone fragment reduction

Having completed Stage 10 and clicked the Fwd button, in the field of the program window one can see X-rays with the bone fragments markers in the position set on the Step 8 (Fig. 53).

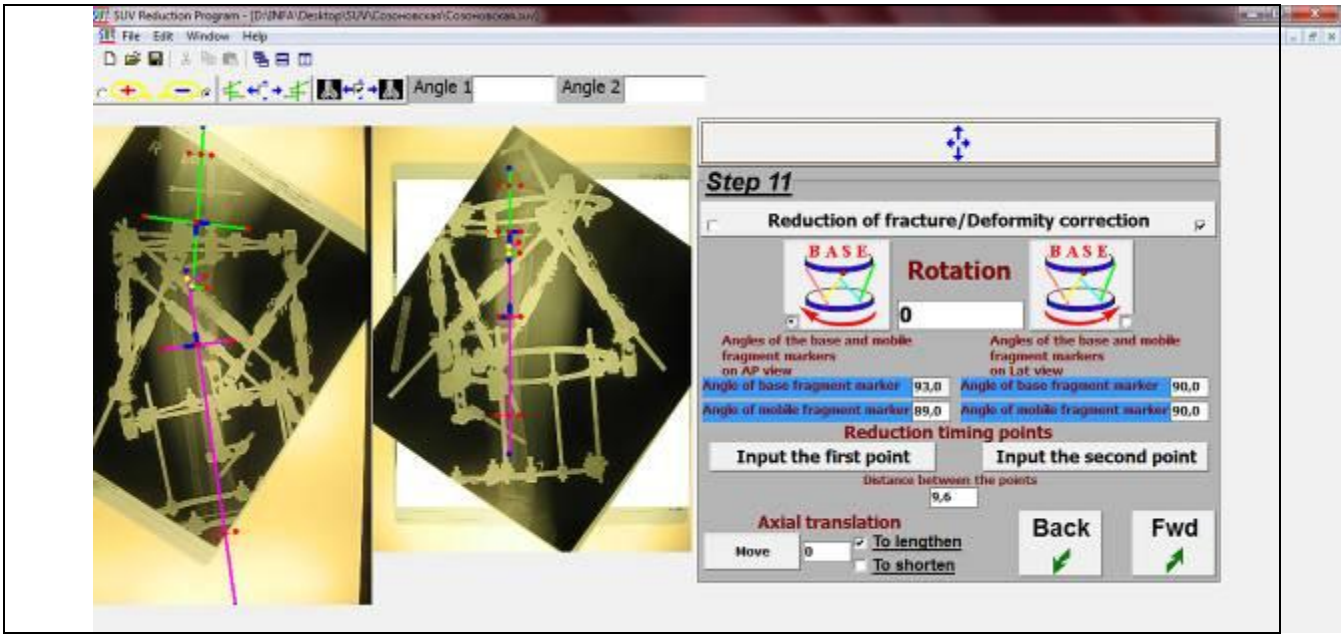


Fig. 53. Ortho-SUV program window for Step 11: X-rays and axes of the proximal and distal fragments

On this step it is possible to make correction of the markers settings for the bone fragments in the following cases:

- if this step shows that the bone fragments markers set on Step 8 are not correct enough;
- if the length of one of the bone fragments is small and in order to draw the anatomical axis of the bone fragment it is necessary to construct an epidiaphyseal (anatomical) angle;
- if there is a planned correction of the bone fragments position using mechanical axes;
- when correction does not imply alignment of the basic and mobile bone fragments axes, for instance, performing reconstruction surgeries such as Ilizarov reconstruction of the proximal part of the femur (pelvic support osteotomy), necessity of hypercorrection of the bone fragments position etc.

To correct the set markers of the bone fragments one should deal with the full range of possible manipulations with the bone fragments markers.

Moving the bone fragments markers

To move a marker of the bone fragment click the “move object” button. Pointing the mouse cursor on any dots on the bone fragment left-click the mouse button and holding it move the marker across the window.

Angular position of the bone fragment marker (mostly required in reconstruction surgeries) is changed in one of the following ways:

- the mouse cursor is located on the point of intersection of the axial line and centering line. Left-click and holding the mouse button change the intersection point position. At the same time the fragment marker begins to rotate around the intersection point of the axial line and the line of the angle marker.
- the mouse cursor is located on the intersection point of the axial line and the line of the angle marker. Left-click and holding the mouse button change the position of the intersection point. At the same time the fragment marker begins to rotate around the intersection point of the axial line and centering line.
- the mouse cursor is located over one of the end points of the centering line. Left-click and holding the mouse button change the position of the point. At the same time the second end point of the centering line remains fixed while the other elements of the fragment marker rotate around the intersection point of the axial line and the angle marker line.

- the mouse cursor is located over the opposite to the angle marker end point of the angle marker line. Left-click and holding the mouse button change the position of the point. At the same time the second end point of the angle marker line remains fixed while the other elements of the fragment marker rotate around the intersection point of the axial line and the centering line.

Angle marker

Angle markers are present on each marker of the bone fragments ("tree" signs) (Fig. 42). They are marked with blue color and show the angle between the axial line and the angle marker line. On the detached panel on Step 11 there are fields (absent on Step 8), which automatically show the values of the marker angles of the basic and mobile bone fragments for anterior and lateral views (Fig. 54 b, showed with an arrow). The angle of the bone fragment marker and the location of the angle marker line relating to the axial line are changed in two ways:

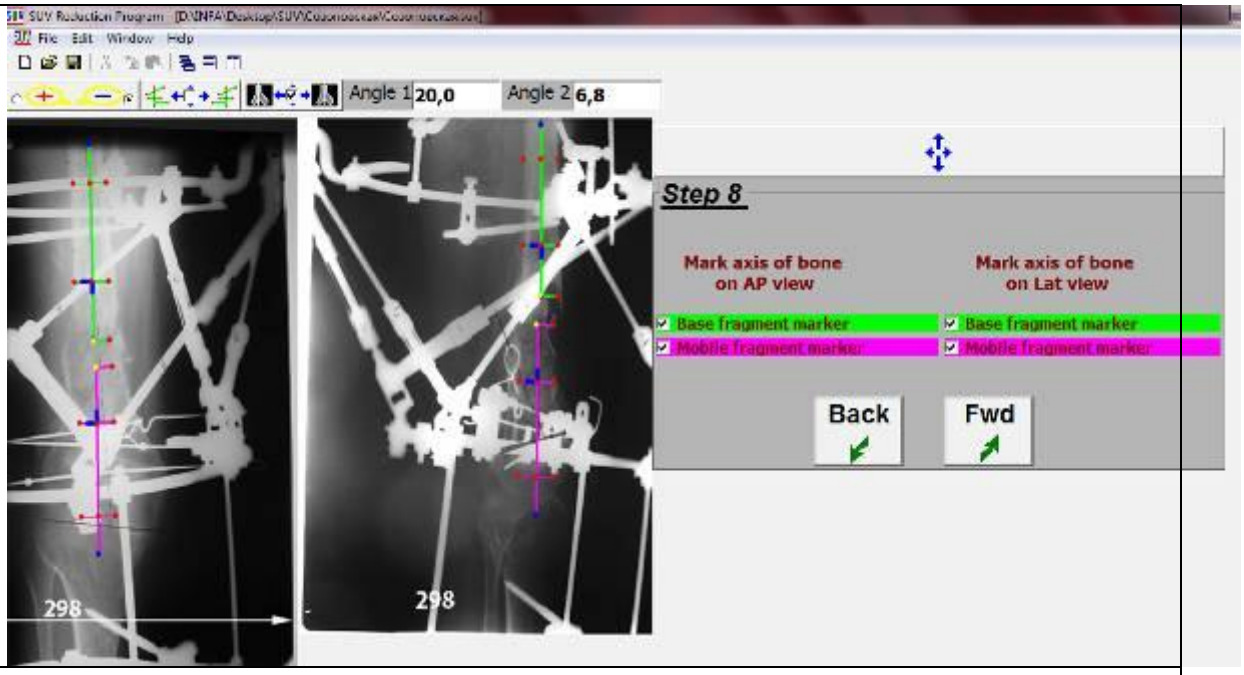
- locate the mouse cursor over one of the ends of the angle marker line, left-click and holding the mouse button change the angle position of the marker line relating to the axial line. Monitoring of the angle value changes is simultaneous during the manipulation since the current values are shown in the field of the marker being changed.

- in the window with the fragment angle marker, which is being corrected, change the current value to the required one. To do it, locate the mouse cursor on the field showing the value of the angle marker (for example, the marker angle of the basic bone fragment on the anterior view). Left-click and set the text cursor in the field. Using Delete and Backspace keys on the keyboard erase the current value. Input the new value. Left-clicking the blue field located on the left side from the value field, confirm the new value of the angle. After these manipulations the position of the marker line of the bone fragment will change automatically relating to the axial line.

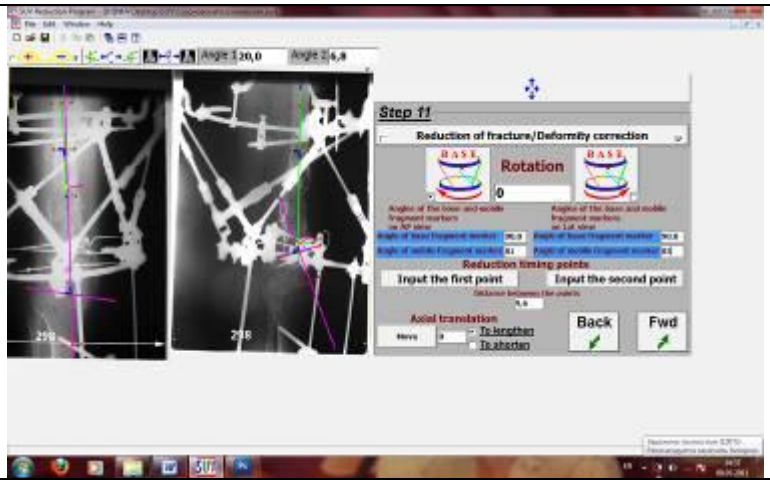
Using angle markers is necessary in two cases:

Firstly, when the fracture or the deformity angle is located close to the joint, which prevents (does not allow) constructing the axis for this short bone fragment. For example, Fig. 54 shows a deformity of the distal metaphysic of the femur. After Step 8 the markers of the bone fragments are set in projections of the bone fragments (Fig. 54a); they also keep this position after Step 10. The known point and angle of the normal intersection of the anatomical axis and knee joint line for the anterior view is 81º (79º-83º) and for lateral view – 83° (79-87º). Using one of the abovementioned methods, to construct the anatomical axis of the short distal fragment set the marker angle of the mobile bone fragment to the value of 81º for the anterior view and 83º for the lateral view.

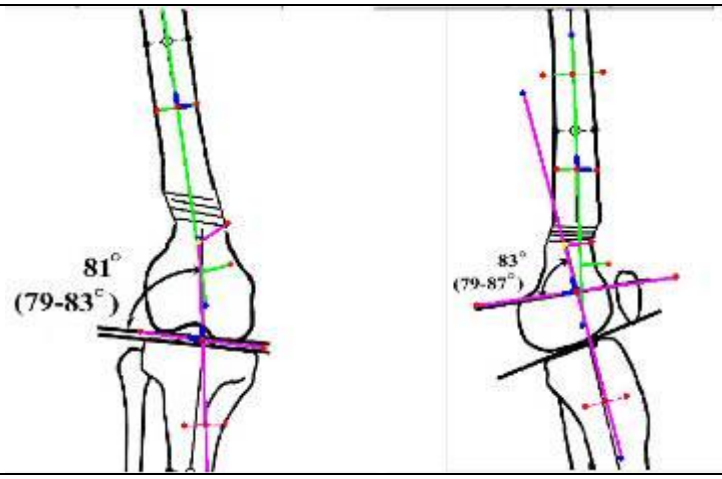
The "tree" marker of the bone fragment is set in the following way: the angle marker line must be located on the projection of the knee joint line while the axial line must intersect the angle marker line in the normal intersection point of the anatomical axis and knee joint line (Fig. 54b,c).



a



b



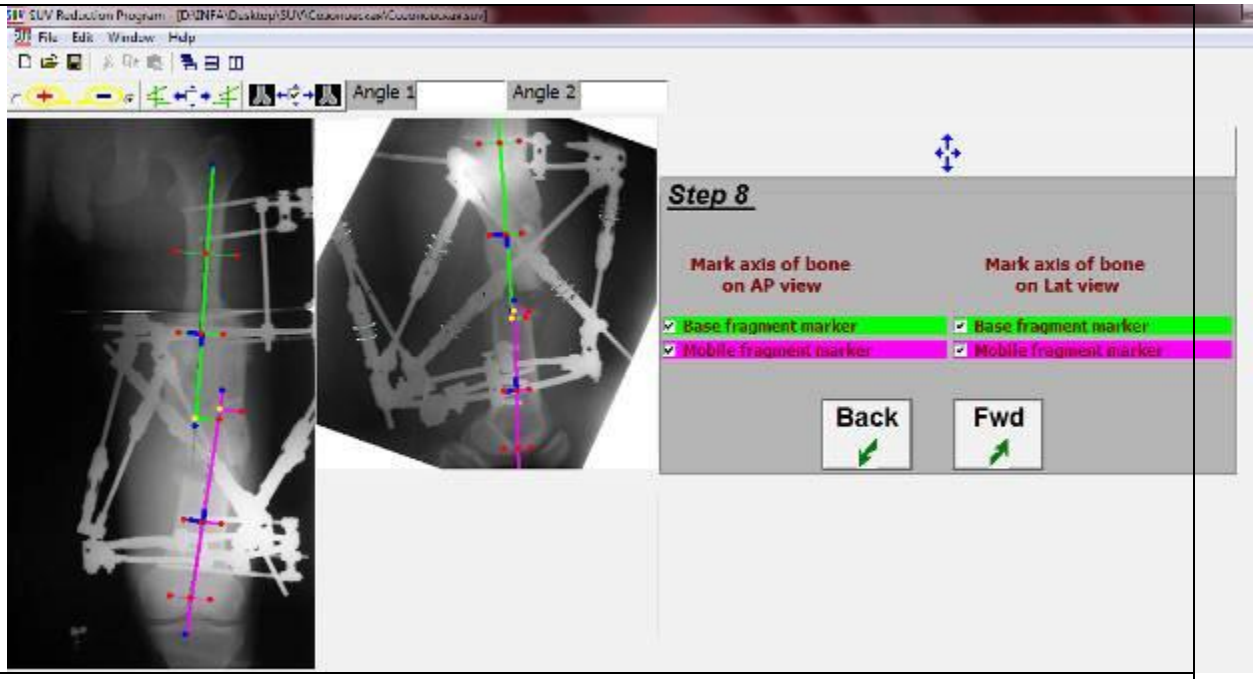
c

Fig. 54a-c. Ortho-SUV software: setting of the angle marker lines in case of pathology of the distal metaepiphysis of the femur; a – setting the markers of the bone fragments after Step 8. b – setting the markers of the bone fragments after Step 11 (arrows point on the fields showing the values of the marker angles of the basic and mobile bone fragments for anterior and lateral views). c – scheme

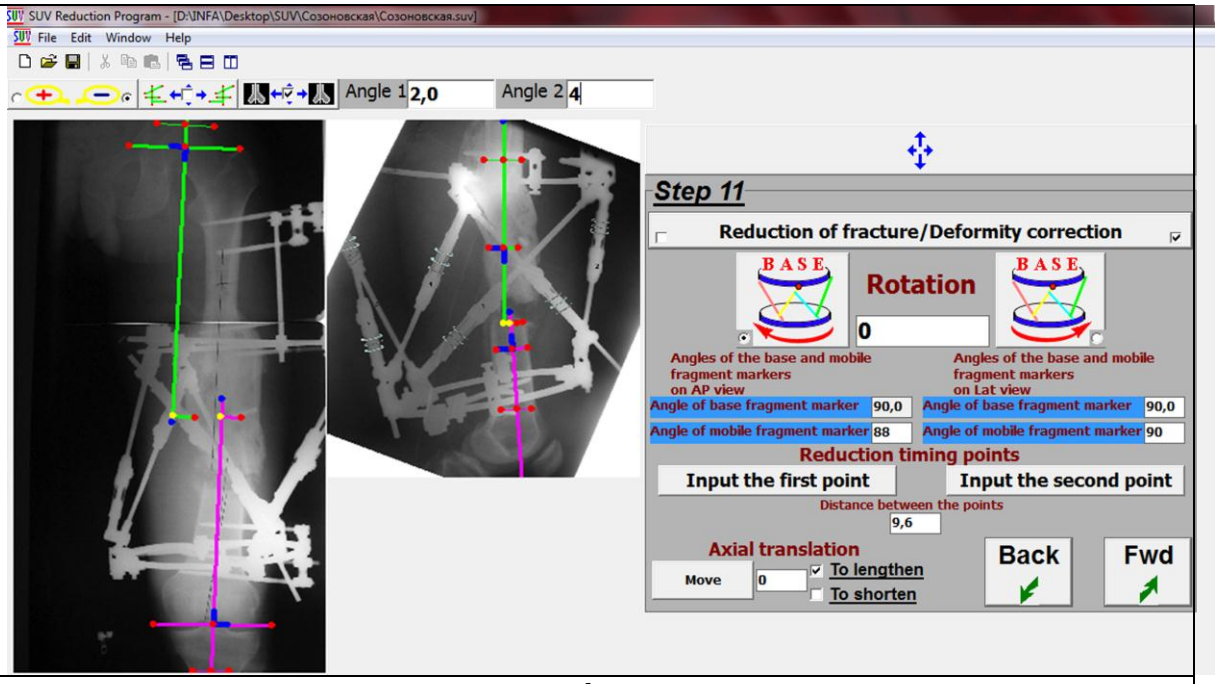
Secondly, angle markers are used in cases when planning of the deformity correction is performed based on the mechanical axes of the bone fragments.

After Step 8 the markers of the bone fragments are set in the opposite of the bone fragments (Fig. 55 a); this position is also kept after Step 10. It is known that the normal mechanical axis of the lower extremity intersects the line connecting the center of the femur head with the apex of the greater trochanter at an angle of 90º (85–95º) in the point located in the center of the femur head. The mechanical axis also intersects the middle part of the knee joint in its center at an angle of 88º (85-90º).

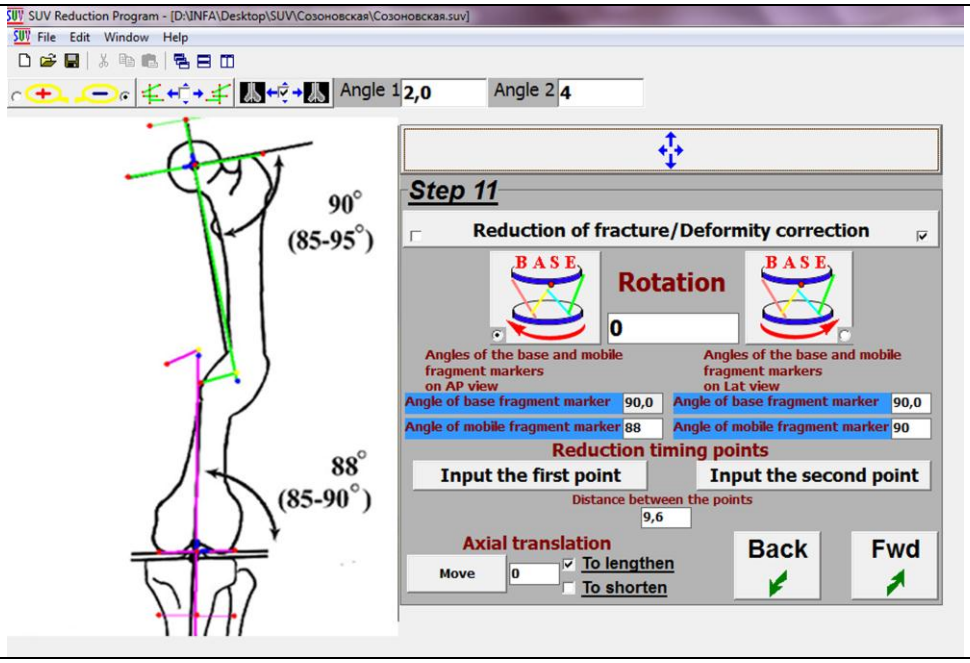
To set the markers of the bone fragments ("tree" signs) a number of manipulations are made. Using one of the abovementioned methods input 90º value of the marker angle of the basic bone fragment on the anterior view. Move the marker of the basic bone fragment so that the line of the angle marker is in the projection of the line connecting the center of the femur head with the apex of the greater trochanter while the axial line intersects it in the center of the femur head. Using one of the abovementioned methods input 88º value of the marker angle of the mobile bone fragment on the anterior view (Fig. 55 b, c). Relocate the marker of the mobile bone fragment so that the line of the angle marker is in the projection of the knee joint line while the axial line intersects it in the center of the knee joint.



a



b



c

Fig. 55a-c. Ortho-SUV software: setting the lines of the angle markers in correction of the femur deformity according to the mechanical axes. a – setting the values of the bone fragments after Step 8. b – location of the markers of the bone fragments after Step 11. c – scheme

Pop-up menu options

On Step 11 options of the pop-up menu are actively used. To see this menu right-click the mouse button in the program window (Fig. 56).

In the pop-up menu there are the following options:

1. “Visibility of the panel”. If to left-click this option the panel appears or disappears. Only X-rays and tools bar stay visible in the program window.

2. “Visibility of bone fragments markers”. Left-clicking on this option leads to appearance or disappearance of the bone fragments markers.

3. “Visibility of bone fragment contours”. Left-clicking on this option leads to appearance or disappearance of the bone contours.

4. “Visibility of the rulers”. Left-clicking on this option leads to appearance or disappearance of the rulers.

5. “Visibility of the vertical and horizontal lines”. Left-clicking on this option leads to appearance or disappearance of the vertical and horizontal lines, which mark the points to calculate the time for the deformity correction.

6. “Visibility of the frame”. Left-clicking on this option leads to appearance or disappearance of the hexapod model constructed on Step 7 (red lines and strut projections).

This pop-up menu can also be used before Step 11. Though, it becomes actual just on Step 11.

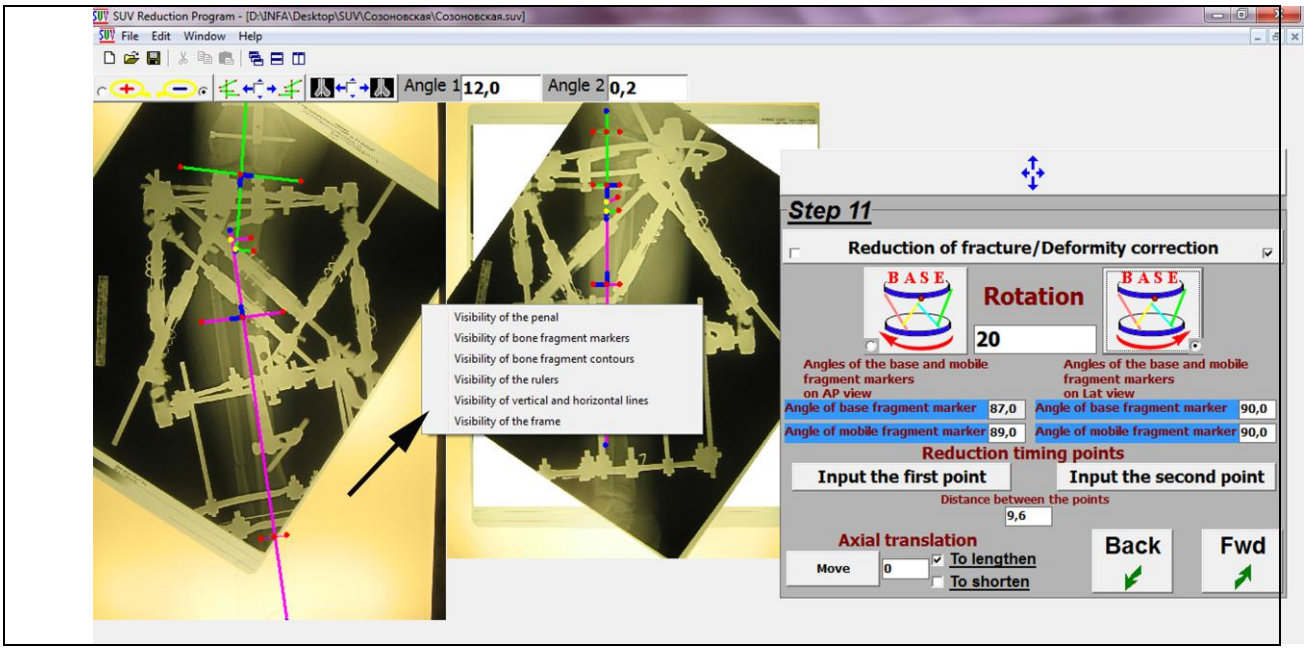


Fig. 56. Ortho-SUV program window on Step 11: right-click is made (the arrow points on the pop-up menu)

Bone contours

To switch on the bone contours on Step 11 choose the proper option from the dropdown menu. In the X-ray field both initial (yellow) and final (red) bone contours appear (Fig. 57). Final bone contours show position of the bone fragments after fracture reduction or deformity correction. The correct position of the final bone contours depends on following the rules of setting the bone fragments markers. When the position of the bone fragments markers is changed the final bone contours position also changes. Bone contours should be used in all cases of deformity correction and reduction of fractures since they enable to visually assess the planned final position of the bone fragments.

Bone contours function is most beneficial in cases when the bone fragments are to be positioned in a special way, which does not correspond with alignment of the anatomical (mechanic) axes of the bone fragments. It can be, for example, in case of esthetic reconstructions (Chapter 2.10), Ilizarov reconstruction of the proximal part of the femur (Chapter 2.15.4).

Having set the markers of the bone fragments and/or the final bone contour taken the correct position, choose “Fracture reduction” or “Deformity correction” option. To do this, check the check-box in the appropriate field (Fig. 57).

“Fracture reduction” option is used in fracture reduction. Its peculiarities are that, while calculating, besides the alignment of the bone fragments axes there is a fitting of the connection points previously marked on each bone fragment. It is most important in anatomical reduction of an oblique spiral fracture. In such cases the rotation displacement of the bone fragments relating to each other is almost impossible to measure clinically and on an X-ray. The result is an inaccurate anatomical reduction with the rotation moment left and partial diastasis between the

fragments. “Fracture reduction” option due to the accurate calculation of matching the connection points enables to perform anatomical without the mentioned inaccuracies.

“Deformity correction” option can be used both in deformity correction and in reduction of fractures. Choosing this option the program ignores the connection points. When using this option, the levels of the markers points just show the necessity of compression and distraction.

Besides, choosing the “Deformity correction” option enables to input the value of the necessary rotation movement of the mobile bone fragment. The appropriate check-box is checked (internal or external rotation) and the rotation value is entered in degrees (Fig. 57).

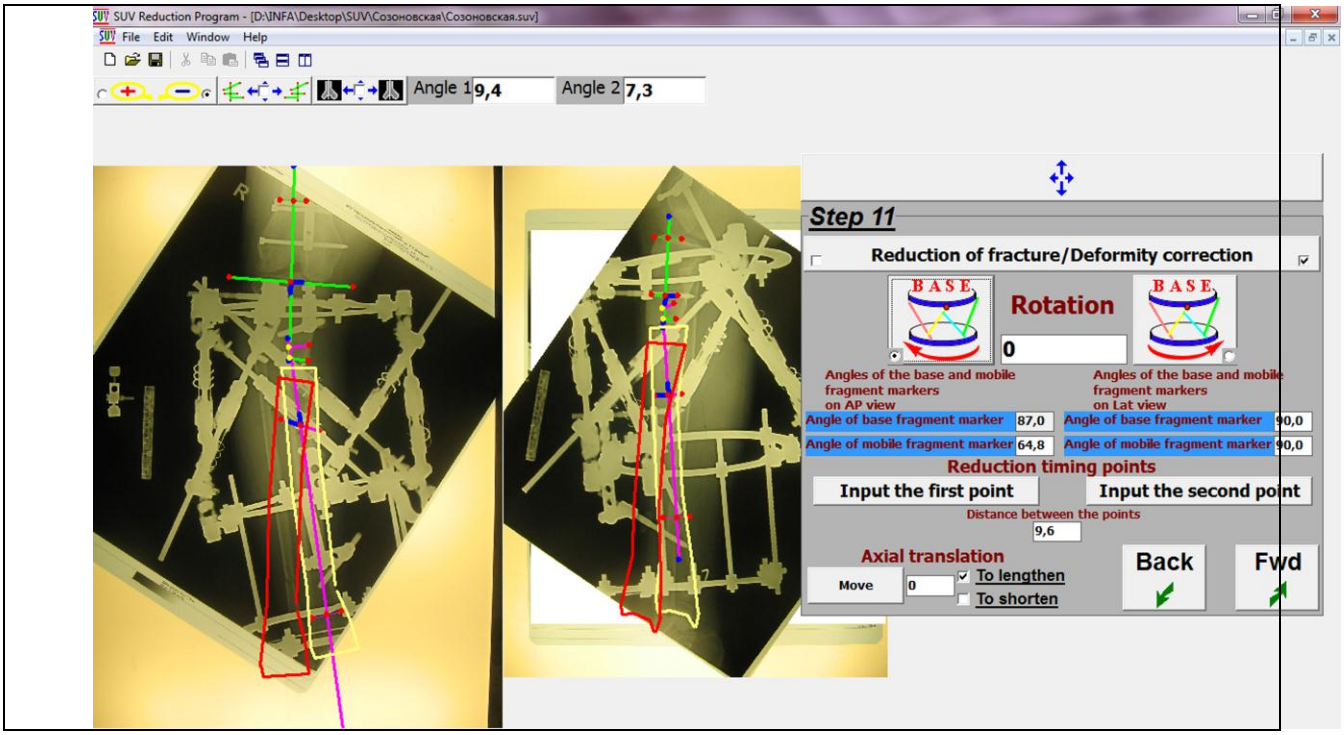


Fig. 57. Ortho-SUV program window on Step 11: the “Deformity correction” option is chosen, the value and direction of the mobile bone fragment rotation are set. The yellow bone contour shows the initial position of the mobile bone fragment; the red bone contour shows the bone fragment position in the result of correction.

On Step 11 additional values are entered to calculate the time of the deformity correction (reduction of the fracture). To do it, on the X-ray images two points are marked, which are called “structures at risk”.

In the pop-up menu (after right-clicking the mouse button over the field of X-rays) choose the “Visibility of the vertical and horizontal lines” option. After pointing the cursor on this option and left-clicking on it one can see intersecting at the right angle green vertical and horizontal lines on the opposite of each X-ray (one intersection on the opposite of each X-ray). Such intersection can be moved across the window in the X-ray field. To do it, the mouse cursor is pointed over the intersection or one of the lines involved in it. Holding the left button of the mouse, move the intersection across the X-ray field and set in the required point.

The first point is set on the line of the osteotomy (fracture) on the spot from which this point will further be moved on the longest distance when the mobile bone fragment is being reduced. In case of angular deformities this point is located on the concave surface (Fig. 58, 59a). Having set the first point on the chosen spots on the anterior and lateral views, click the “Input the first point” button (Fig. 59a).

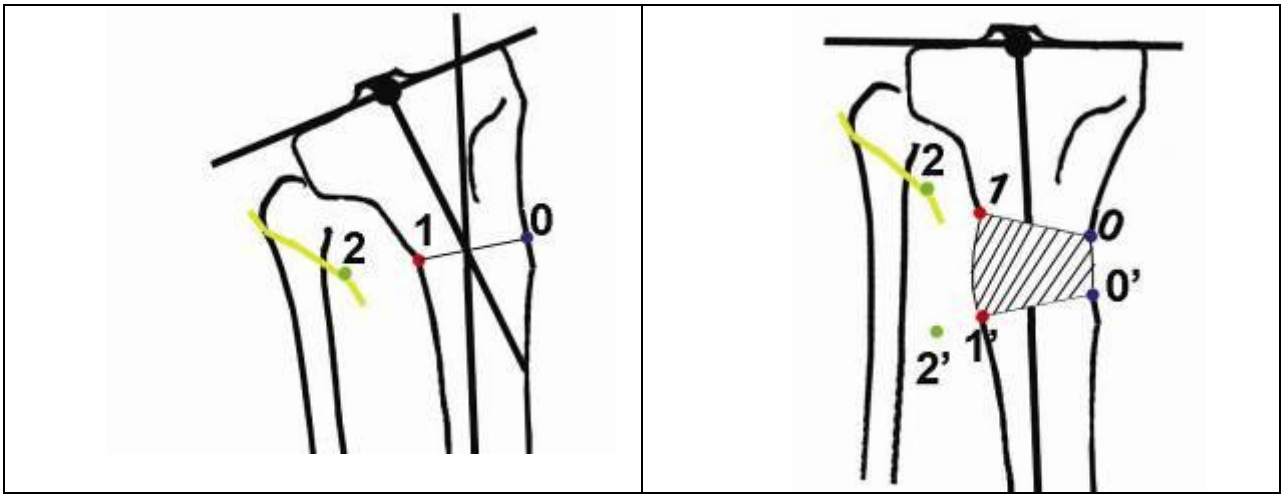
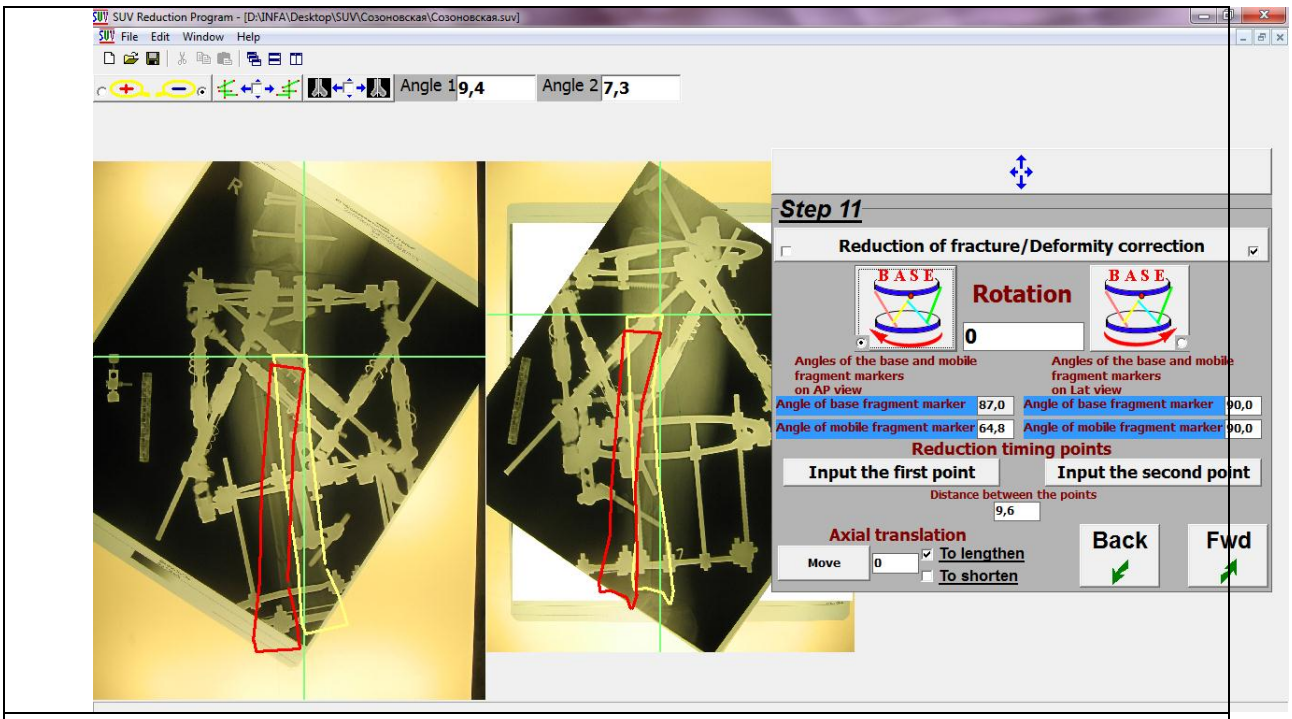


Fig. 58. Point 1 in case of the deformity correction must pass the distance (1-1'), which is longer than that of point 0 (0-0'), but shorter than that of point 2 (2-2'), located in the projection of the fibular nerve

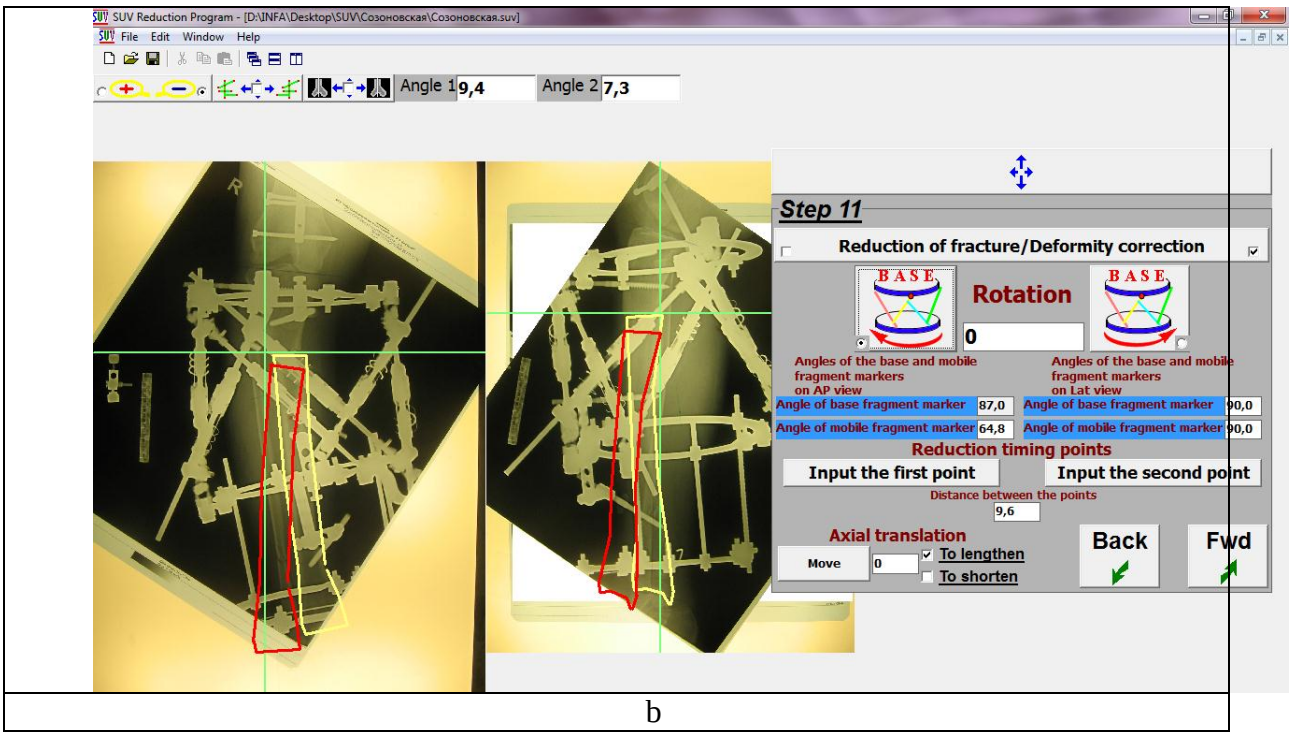
The second point is set in the projection of the main vessels and nerves where they will be maximally stretched, while performing the deformity correction (Fig.58, 59).

Having set the second point on the chosen spots on the anterior and lateral views, click the "Input the second point" button (Fig. 59b).

Besides entering the "structures at risk" the intersections of the vertical and horizontal lines can be used for different measurements on the X-rays. Thus, one can measure the maximal distance, which the bone will pass during the deformity correction period. To do this, locate one intersection in the opposite of one of the points on the initial bone contour on the anterior and lateral views and click the "Input the first point" button. After that the intersection of lines is located against the appropriate point on the final bone contour on the anterior and lateral views (the place where the first point will be after the deformity correction) and click the "Input the second point" button. In the field of the program bar the distance between the points will be indicated.



a

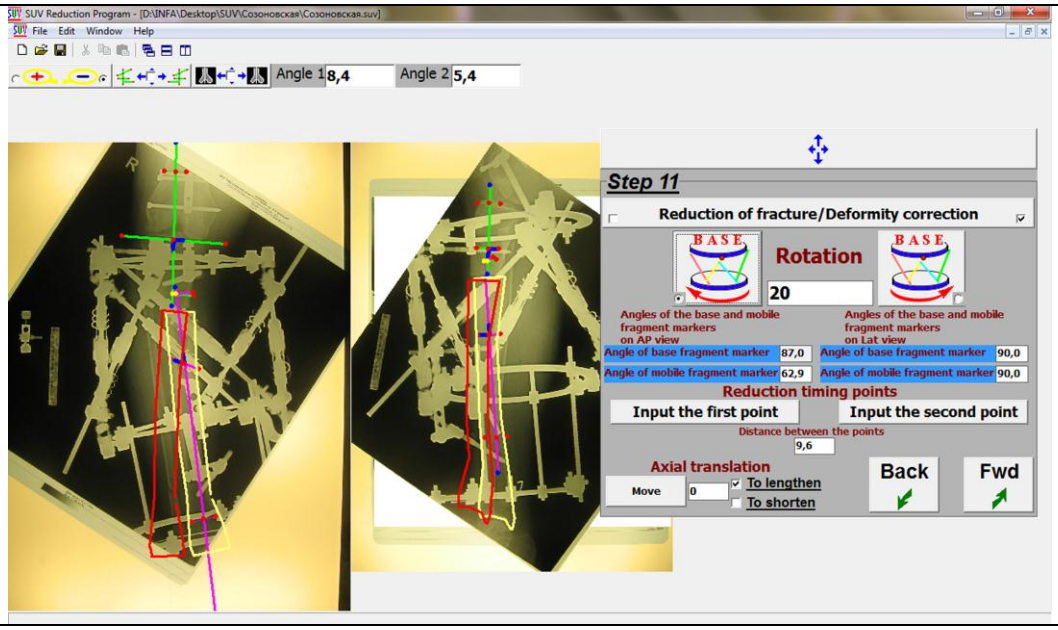


b

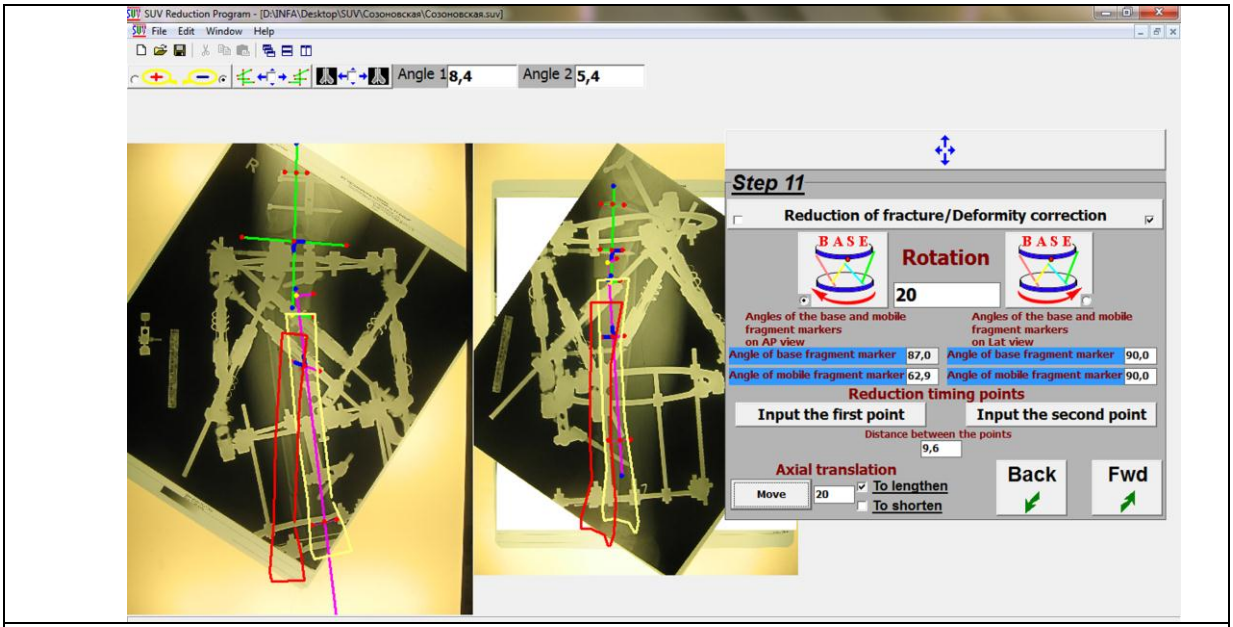
Fig. 59a,b. Ortho-SUV program window on Step 11: the chosen points, which during the deformity correction will pass the longest distance: a – Point 1 passes the longest distance during reduction. b – Point 2 shows the projection of main vessels and nerves

Besides, on Step 11 there is a program option to input the value of the distraction or compression between the bone fragments. To do this, the lines of the connection points of the proximal and distal markers of the bone fragments are set at one level (Fig. 60a). In the bar field "Axial translation" check the check-boxes in front of the appropriate option: "to lengthen" or "to shorten". Input the value of the required compression or distraction in mm in the appropriate field. Then click the "Move" button and the lines of the bone fragments markers and bone contours move lengthwise relating to each other on the input distance (Fig. 60b).

NB! The axial translation (compression or distraction) will occur along the axial lines of the basic bone fragments markers.



a



b

Fig. 60a,b. Ortho-SUV program window on Step 11: distraction; a – line markers of the connection points markers are located on the same level, b – after lengthening input by 20 mm

Note, that on Step 11 the tools bar fields “Angle 1” and “Angle 2” show the angles between the axial lines of the basic and mobile bone fragments markers: “Angle 1” for the anterior view and “Angle 2” for the lateral view. This option is especially useful for reconstruction surgeries when the aim of the procedure is not to align the axes of the bone fragments but to create a definite angle between the bone fragments. For example, the Ilizarov femur reconstruction or creating special positions of the bone fragments in esthetic surgery.

Having identified the structures at risk, click “Fwd” button.

NB! Before making a transition to Step 12 check the position of the red bone contour relating to the basic fragment using maximal magnification; otherwise, you cannot notice that there is a slight residual displacement.

Step 12. Strut length change

To define the rate of deformity correction (reduction of a fracture) a value is entered in the “Rate of correction” field (mm/day) (Fig. 61). The default value set is 1 mm/day. Though, a user can input any other value; the minimal value is 0.1 mm.

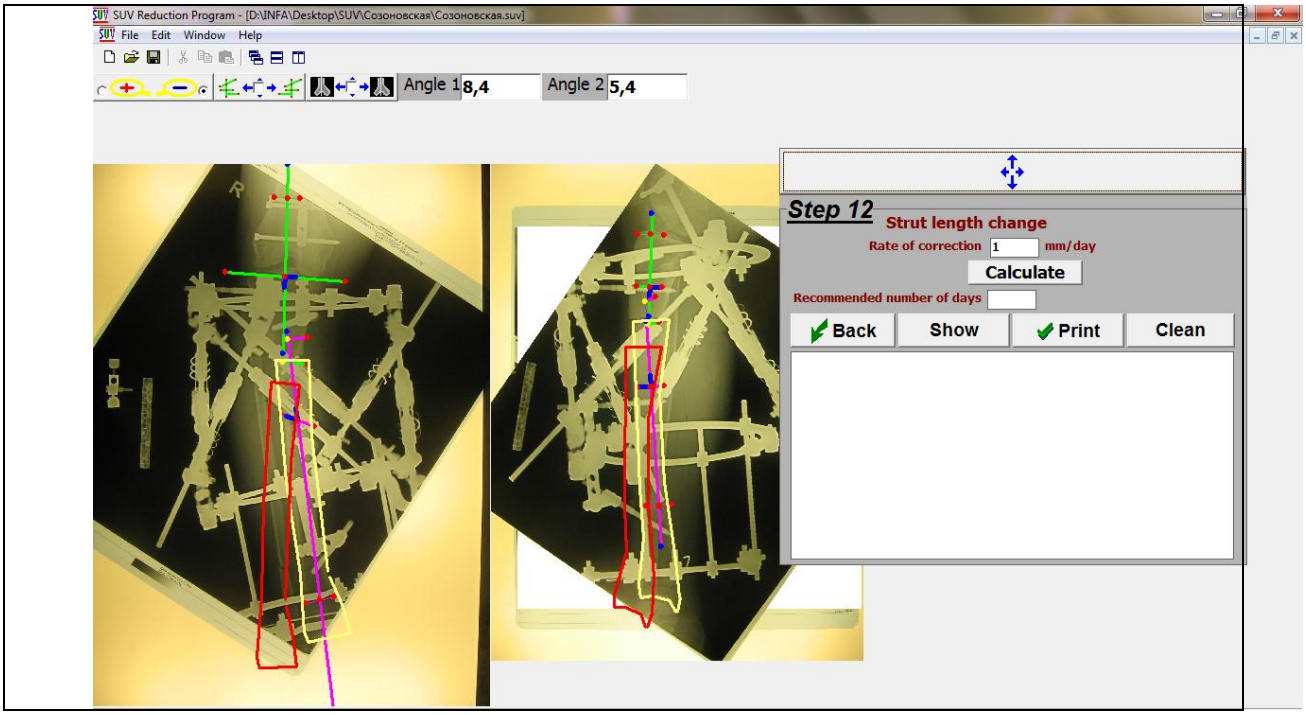


Fig. 61. Ortho-SUV program window on Step 12: the deformity correction rate is input

Then click the "Calculate" button and the program calculates the number of days required for the deformity correction. The calculation results appear in the "Recommended number of days" field (Fig. 62). These values show the situation when neither of the structure at risk must not to be moved faster than the chosen rate, for example, by 1 mm a day. Once again, a user can input any required number of days for the deformity correction in the appropriate field.

Having defined the number of days required for the deformity correction (reduction of the fracture), click "Show" button. After calculations performed the program shows a table in the right lower field of the window, which contains the values of daily changes of each strut length (Fig. 63).

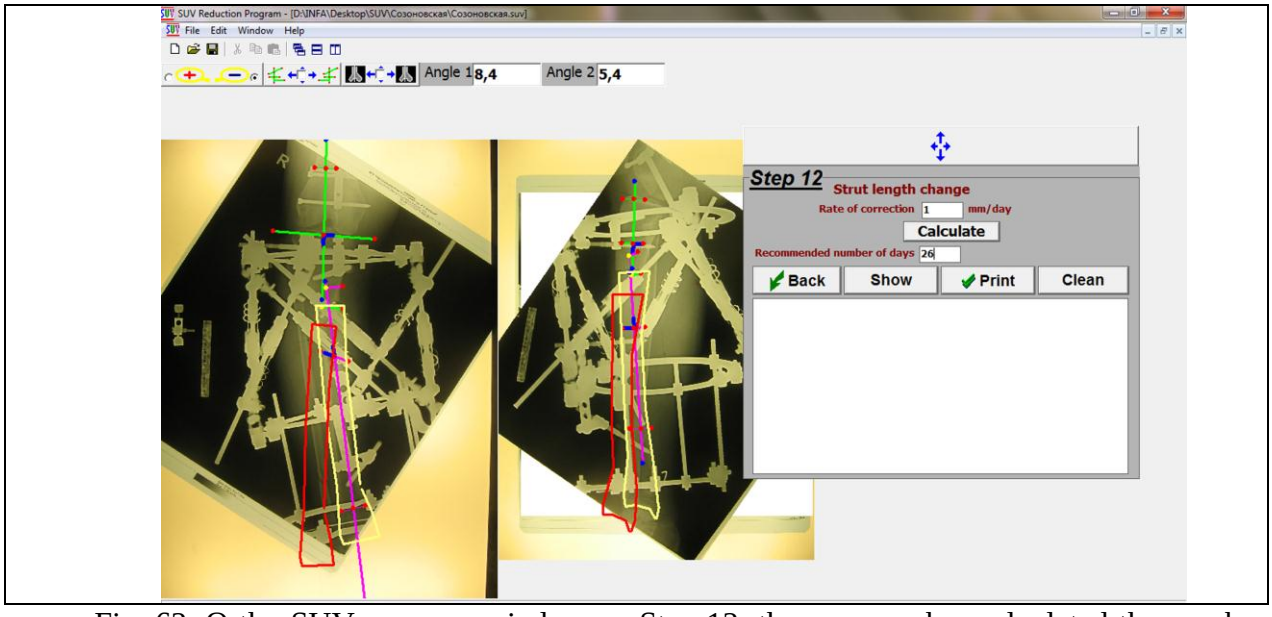


Fig. 62. Ortho-SUV program window on Step 12: the program has calculated the number of days recommended for the deformity correction with 1 mm/day rate, which is 26 days.

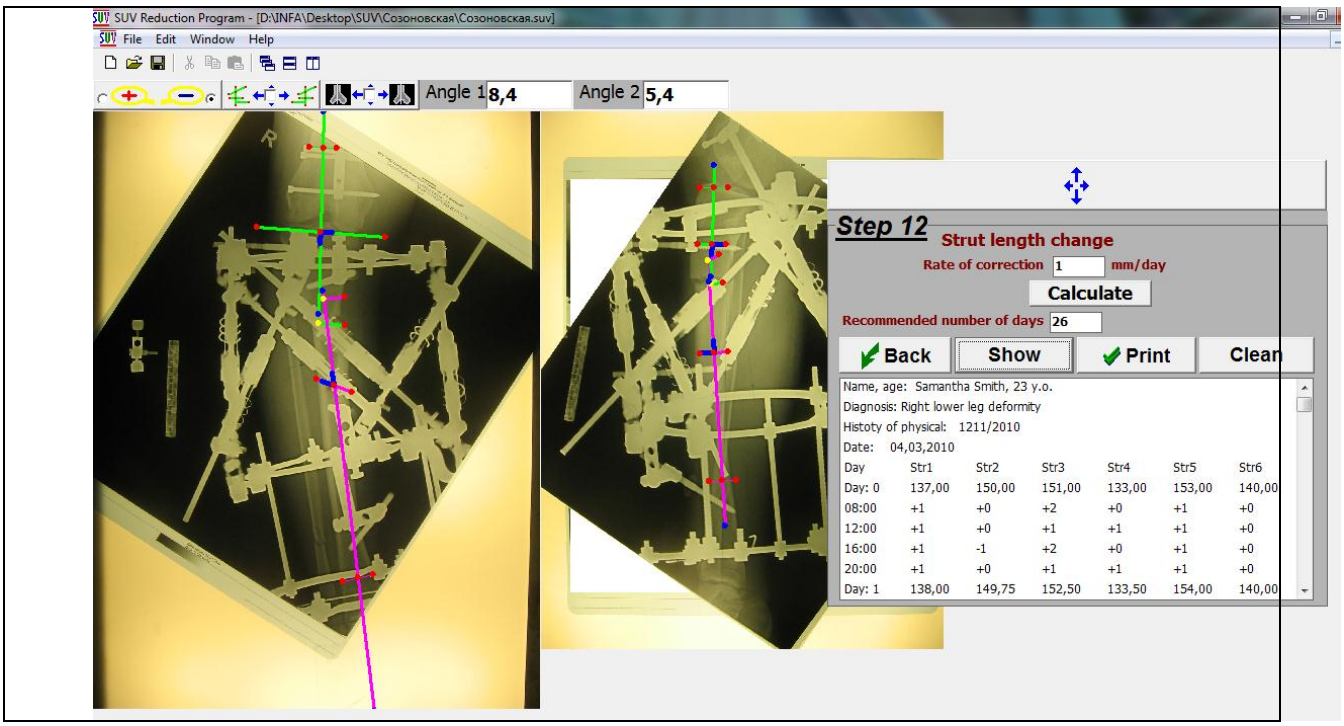

SUV Reduction Program - [D:\INFA\Desktop\SUV\Созоновская\Созоновская.suv]
File Edit Window Help
Angle 1 8,4
Angle 2 5,4
Step 12
Strut length change
Rate of correction 1 mm/day
Calculate
Recommended number of days 26
Back
Show
Print
Clean
Name, age: Samantha Smith, 23 y.o.
Diagnosis: Right lower leg deformity
Histoty of physical: 1211/2010
Date: 04,03,2010
Day Str1 Str2 Str3 Str4 Str5 Str6
Day: 0 137,00 150,00 151,00 133,00 153,00 140,00
08:00 +1 +0 +2 +0 +1 +0
12:00 +1 +0 +1 +1 +1 +0
16:00 +1 -1 +2 +0 +1 +0
20:00 +1 +0 +1 +1 +1 +0
Day: 1 138,00 149,75 152,50 133,50 154,00 140,00

Fig. 63. Ortho-SUV program window on Step 12: the program has calculated daily changes of each strut length to achieve the deformity correction

The first column of the table shows the day when the correction is started. The following six columns show the length of each strut. The rows show appropriate integer values in mm of the struts length for each day. Between the rows there is Delta/0.25 parameter shown for each strut, which identifies how many times and in what direction the strut length is to be changed by 0.25 mm in order to achieve "the daily norm".

If there is no need for further correction of the deformity correction rate and time (or fracture reduction) then click the "Print" button and obtain a paper copy of recommendations for daily length change of each strut. Using the "Clean" button, one can clear the fields of struts length. This function is needed in case if recalculation is required.

The file can be saved on any electronic carrier. To do this, click the "Save" button located on the tools bar.

The program considers the following mode of passing all 12 steps (after certain training including 10-12 calculations):

- 8-12 minutes in case of fractures and diaphyseal deformities;
- 12-15 minutes in case of epimetaphyseal deformities and reconstruction surgeries.

6 Application of Ortho-SUV Frame: clinical cases

6.1 Application of Ortho-SUV Frame in fracture treatment

Patient B., 22 y.o., was hospitalized with the diagnose: old (dated three months back) midshaft fracture of the left tibia with shortening, translation, and angulation of bone fragments (Fig. 64a).

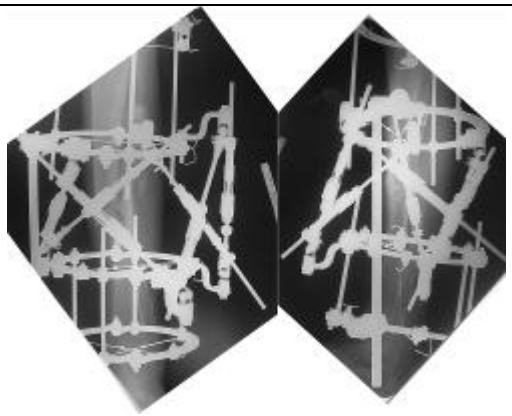
External fixation of left tibia using an Ortho-SUV Frame has been performed. Transosseous elements – wires – were inserted in such a way, so as not to interfere with consequent nailing (Fig. 64b):

$$\frac{\text{I,}\mathbf{9}\text{-3; II,}\mathbf{9}\text{-3}}{2/3\ 140} \_ \frac{\text{IV,}\mathbf{3}\text{-9}}{140} \_ \text{Ortho-SUV} \_ \frac{\text{IV,}\mathbf{3}\text{-9}}{140} \_ \frac{\text{IX (}\mathbf{8}\text{-2)IX,8-2; IX,}\mathbf{4}\text{-10}}{140}$$

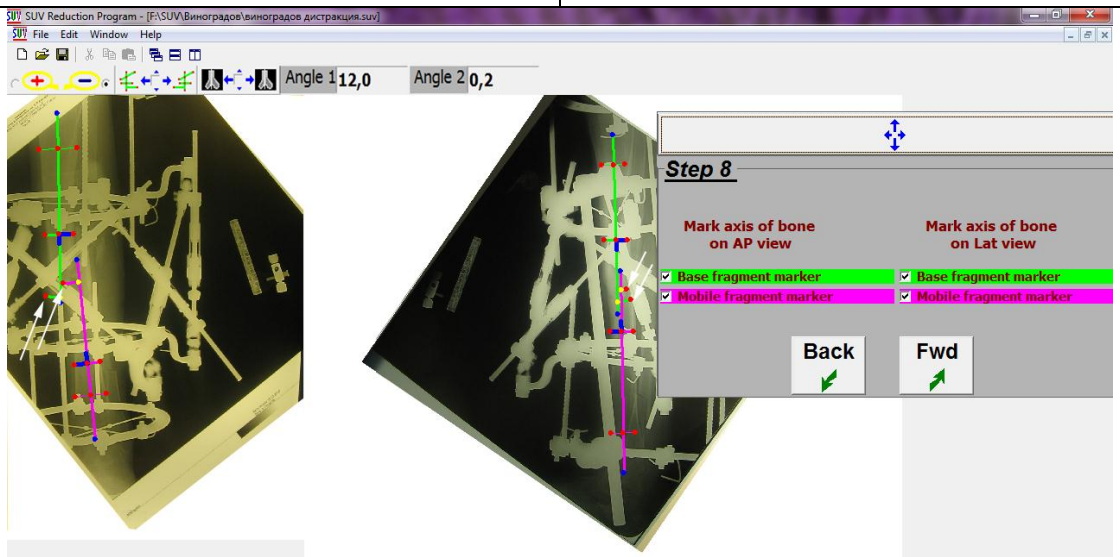
An attempt of close reduction in «fast struts» mode only partially succeeded in improving positioning of the bone fragments, and their displacement remained (Fig. 64c). Calculations were made using Ortho-SUV software. “Fracture reduction” mode was used and superposition point of proximal and distal fragments were indicated (Fig. 64d,e). Proceeding from these calculations (Fig. 64f), fracture reduction has been carried out (Fig. 64g). Second stage involved intramedullary osteosynthesis with locking nail (Fig. 64h,i).

a

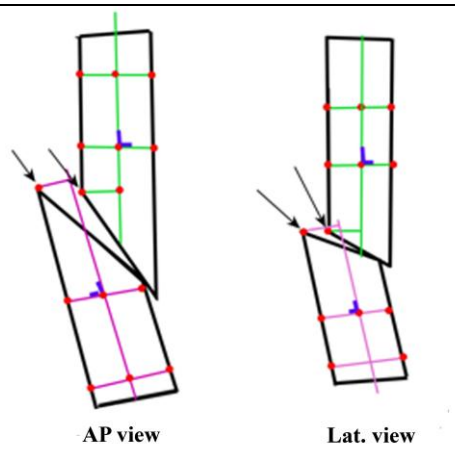
b



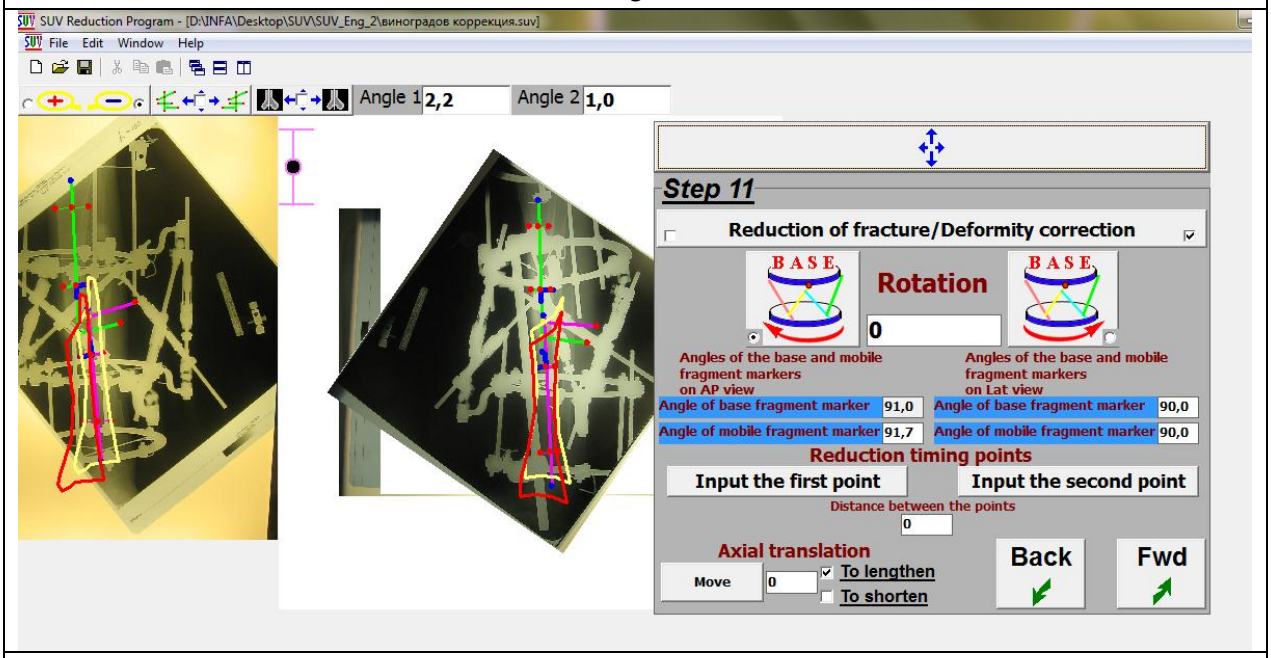
c



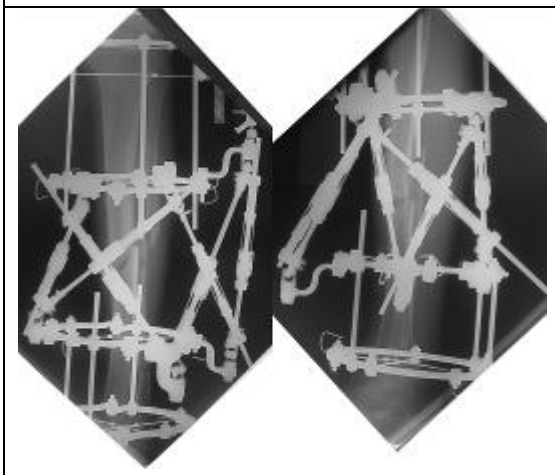
d


AP view
Lat. view

e


SUV Reduction Program - [D:\INFA\Desktop\SUV\SUV_Eng_2\виноградов коррекция.suv]
File Edit Window Help
Angle 1 2,2
Angle 2 1,0
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 91,0
Angle of mobile fragment marker 91,7
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90,0
Reduction timing points
Input the first point
Input the second point
Distance between the points
0
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

f



g

h

i

Fig. 64a-i. Photographs and roentgenograms of patient B.

6.2 Application of Ortho-SUV Frame in diaphyseal deformities

Patient E. (Fig. 65a) was hospitalized with the diagnose: nonunions of distal third in both tibias. Complex six-component, threeplanar deformity of right lower leg. Complex five-component, two-planar deformity of left lower leg.

At first stage, combined external fixation of bones in both right and left lower legs has been performed using with Ortho-SUV devices (Fig. 65b).

For the right leg:

$$\frac{\text{III,12,100; IV,}\mathbf{10}\text{-4; V,2,80}}{150} \text{ _ Ortho-SUV _ } \frac{\text{VI,12,90; VII(}\mathbf{8}\text{-2)8-2; VIII,1,90}}{150}$$

For the left leg:

$$\frac{\text{IV,12,100; V,}\mathbf{10}\text{-4; VI,2,80}}{150} \text{ _ Ortho-SUV _ } \frac{\text{VII,12,90; VIII(}\mathbf{8}\text{-2)8-2; VIII,}\mathbf{4}\text{-10}}{150}$$

While working with the software (consecutively for both legs) at step 11 «deformity correction» mode has been used. Fragment markers were set over projections of anatomical axes of the bone fragments (Fig. 65c,d).

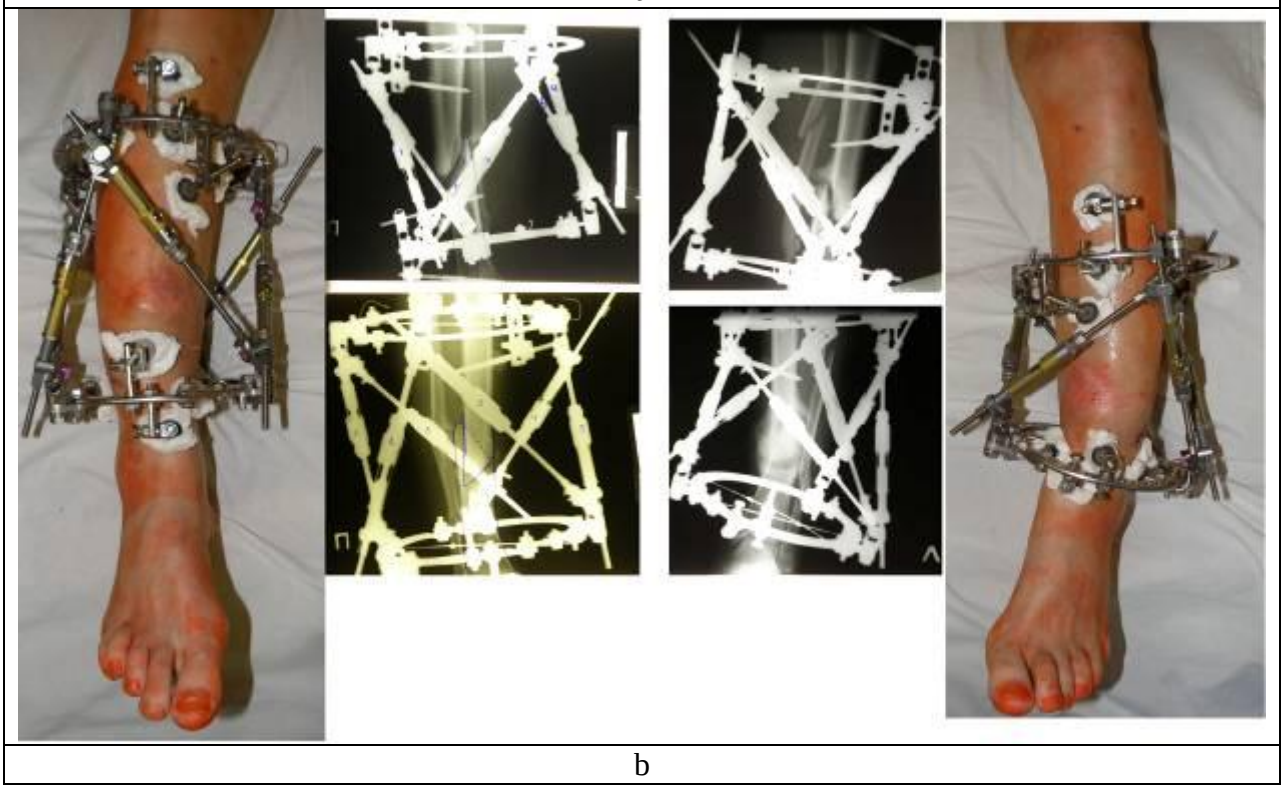
To determine the rate and the period of distraction two points were used - «*points of structures at risk*». For this purpose in the dropout menu (the latter appears after right mouse button has been pressed) "Vertical and horizontal lines visibility switch in/out". After this item had been selected with mouse cursor and the left mouse button pressed, green intersections consisting of one vertical and one horizontal line crossing at right angle to one another appeared next to both of roentgenograms (an intersection for an image). Having pressed left mouse button and keeping it that way, each intersection was moved into its respective image area and set onto a required point.

The first point has been set along the nonunion line, exactly where the mobile fragment in the process of its transport will cover the *longest distance* (Fig. 65e). After the first point had been set into its selected location on the AP and lateral roentgenograms, operator pressed the button «Input the first point". The second point has been set in the area where main vessels and nerves are projected, on the spot, where the latter will get the maximum stretch in the deformity correction process (Fig. 65f). After the second point has been set on its selected locations on AP and lateral roentgenograms, operator pressed the button «Input the second point".

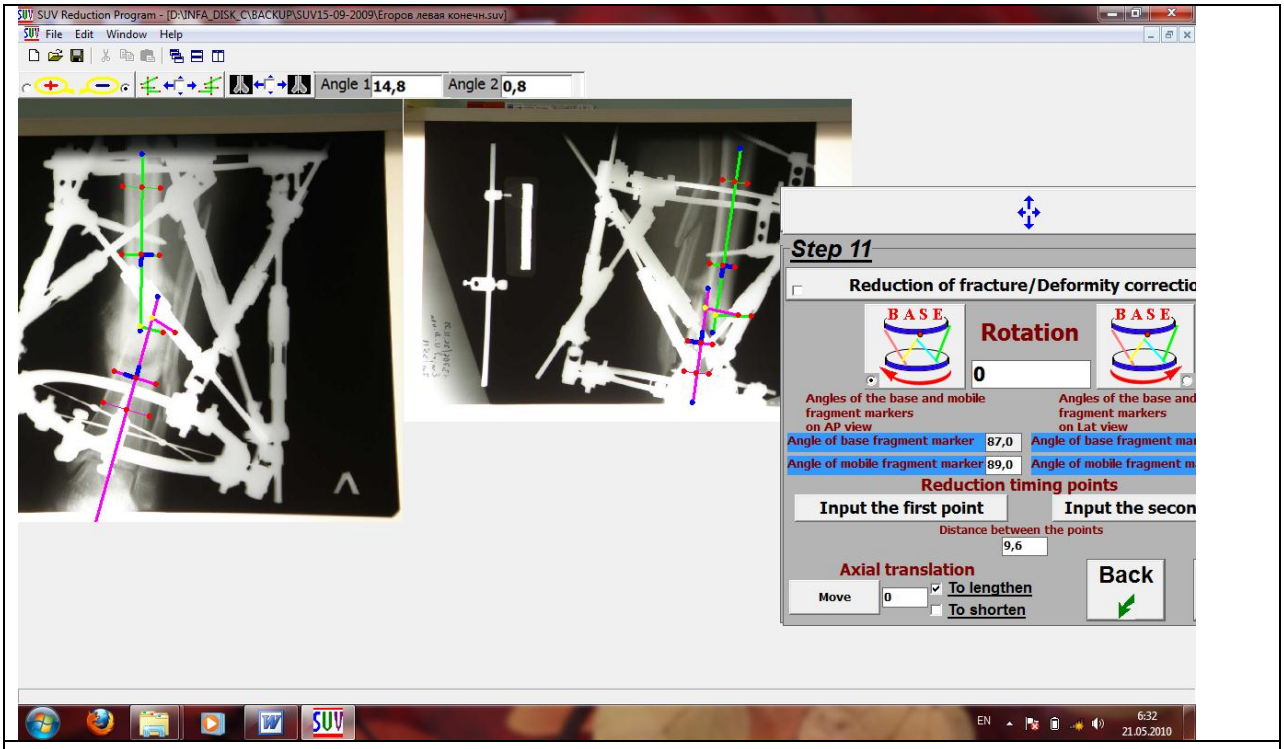
At step 12 the rate of deformity correction - 1 мм per day – was entered. After “Calculate” button had been pressed, program calculated the recommended quantity of days required for correction of the deformity. When operator pressed «Show», at the lower right field of the display a table appeared displaying the values of daily length change for each strut (Fig. 65g). This table was printed out and given to the patient.

Deformity correction has been performed according to these calculations (Fig. 65h). Second stage involved intramedullary osteosynthesis with locking nails of both lower legs (Fig. 65i).

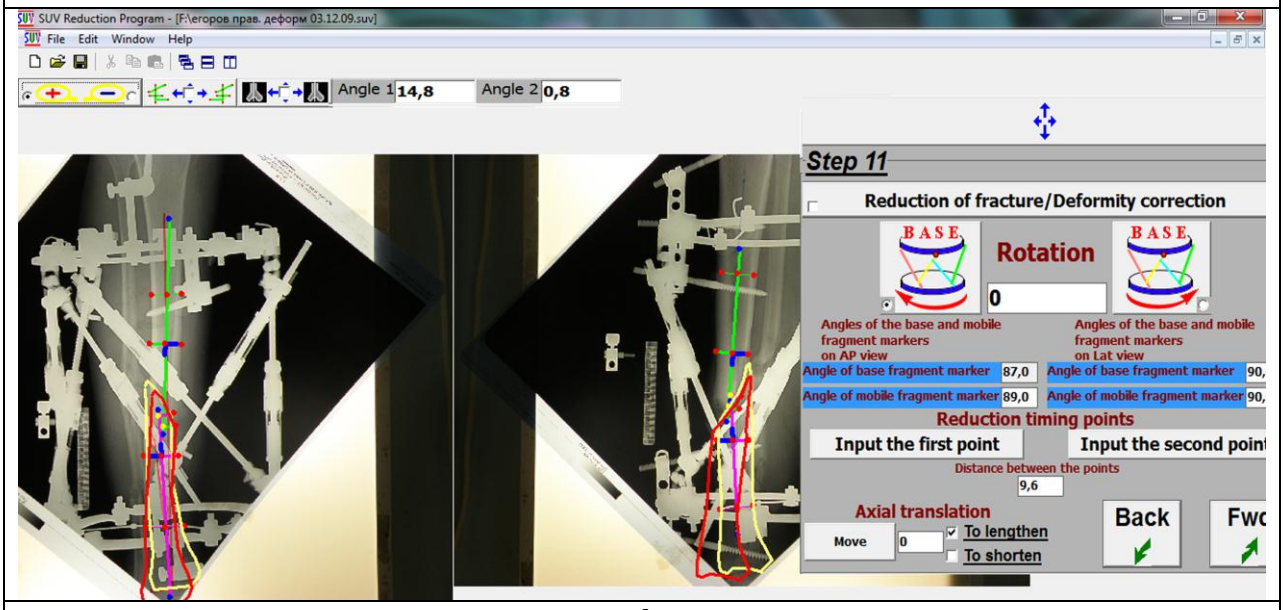
a



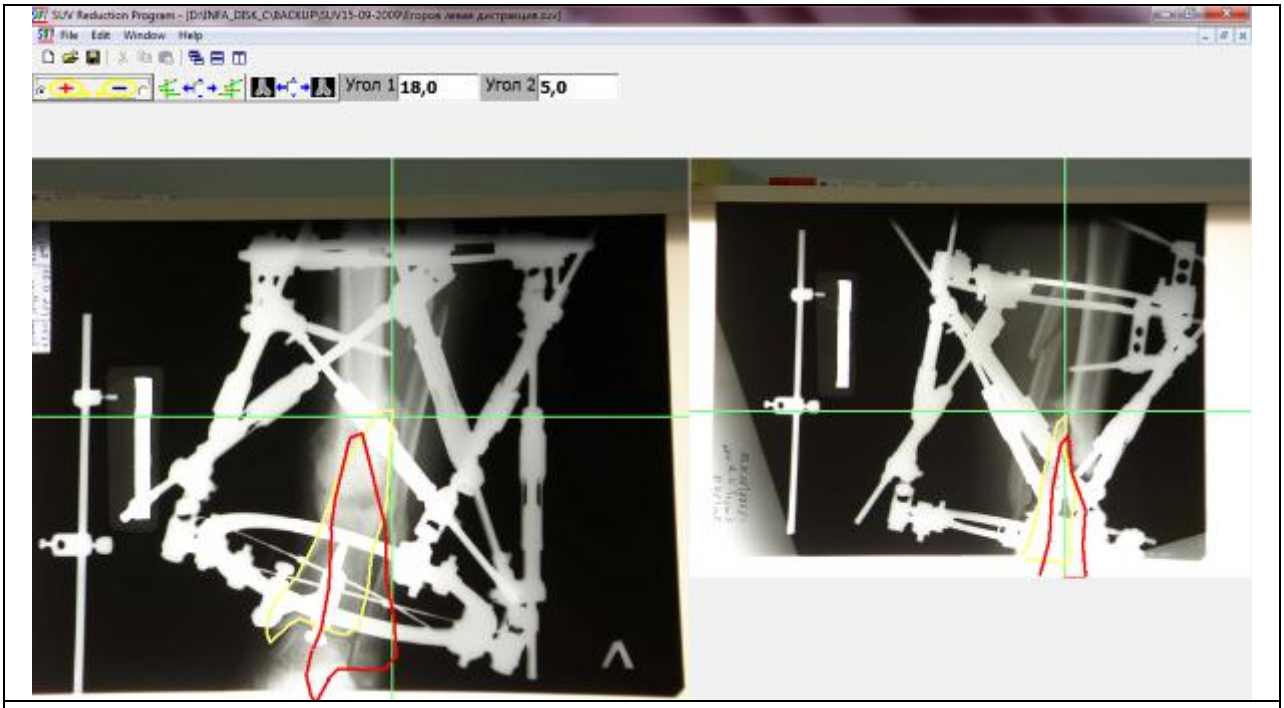
b


SUV Reduction Program - [D:\INFA_DISK_C\BACKUP\SUV15-09-2009\Егоров левая конечн.suv]
File Edit Window Help
Angle 1 14,8
Angle 2 0,8
Step 11
Reduction of fracture/Deformity correctio
BASE
Rotation
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and fragment markers on Lat view
Angle of base fragment marker 87,0
Angle of mobile fragment marker 89,0
Reduction timing points
Input the first point
Input the secon
Distance between the points
9,6
Axial translation
Move 0
To lengthen
To shorten
Back
EN
6:32
21.05.2010

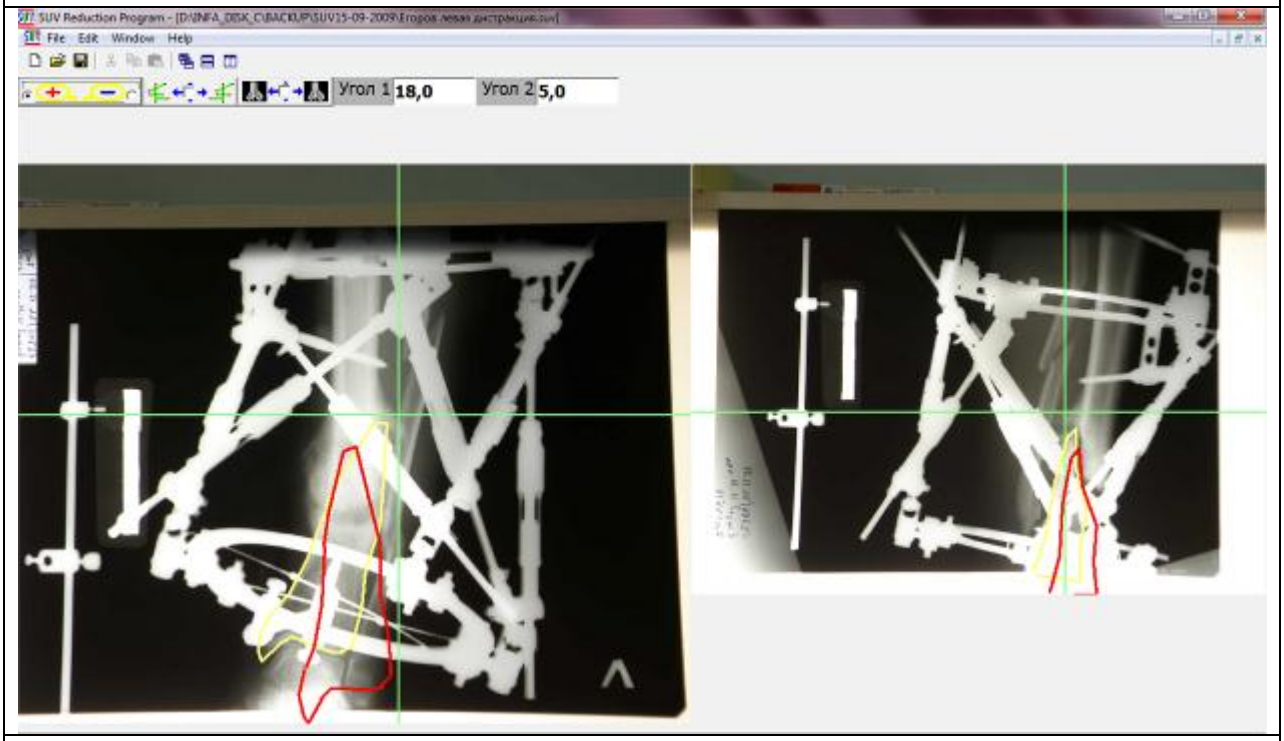
c


SUV Reduction Program - [F:\егоров прав. деформ 03.12.09.suv]
File Edit Window Help
Angle 1 14,8
Angle 2 0,8
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 87,0
Angle of mobile fragment marker 89,0
Angle of base fragment marker 90,
Angle of mobile fragment marker 90,
Reduction timing points
Input the first point
Input the second point
Distance between the points
9,6
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

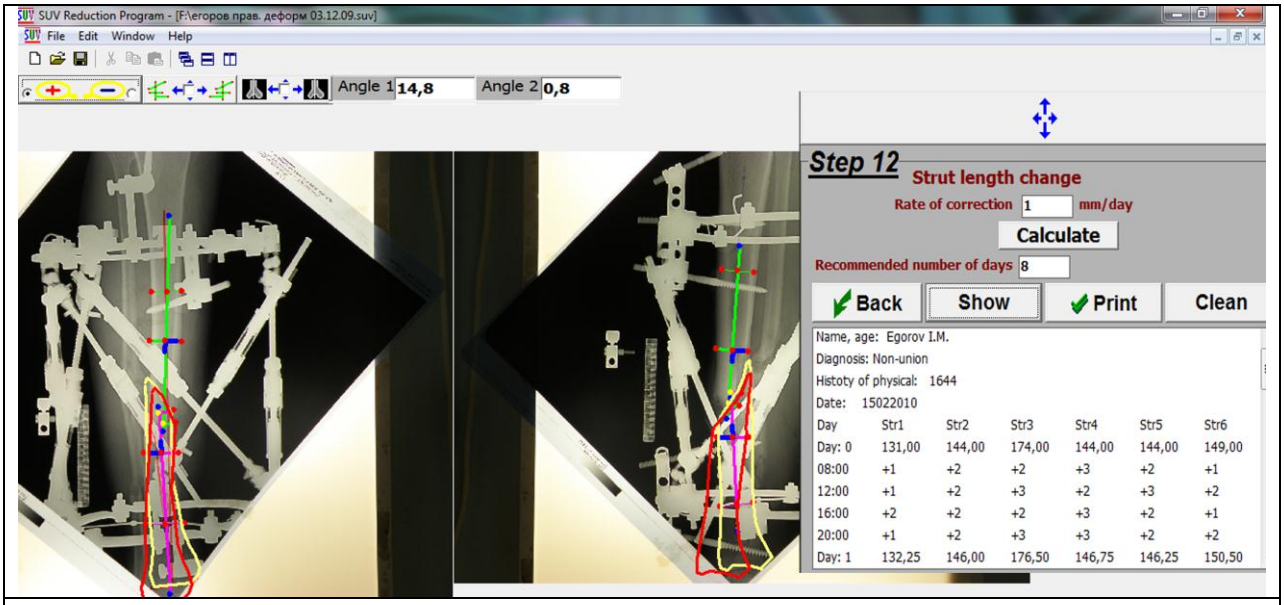
d


File Edit Window Help
Угол 1 18,0
Угол 2 5,0

e


File Edit Window Help
Угол 1 18,0
Угол 2 5,0

f


SUV Reduction Program - [F:\егоров прав. деформ 03.12.09.suv]
File Edit Window Help
Angle 1 14,8
Angle 2 0,8
Step 12
Strut length change
Rate of correction 1 mm/day
Calculate
Recommended number of days 8
Back
Show
Print
Clean
Name, age: Egorov I.M.
Diagnosis: Non-union
Histoty of physical: 1644
Date: 15022010
Day Str1 Str2 Str3 Str4 Str5 Str6
Day: 0 131,00 144,00 174,00 144,00 144,00 149,00
08:00 +1 +2 +2 +3 +2 +1
12:00 +1 +2 +3 +2 +3 +2
16:00 +2 +2 +2 +3 +2 +1
20:00 +1 +2 +3 +3 +2 +2
Day: 1 132,25 146,00 176,50 146,75 146,25 150,50

g

h

i

Fig. 65a-i. Photographs and roentgenograms of patient E. before and during the treatment

Example of diaphyseal deformity correction in the femur, using mechanical axes

Patient E. was hospitalized with the diagnosis: posttraumatic complex five-component biplanar deformity of left femoral bone.

To correct the deformity an Ortho-SUV frame was used (Fig. 66a,b). Fragment markers were set over the mechanical axes of bone fragments.

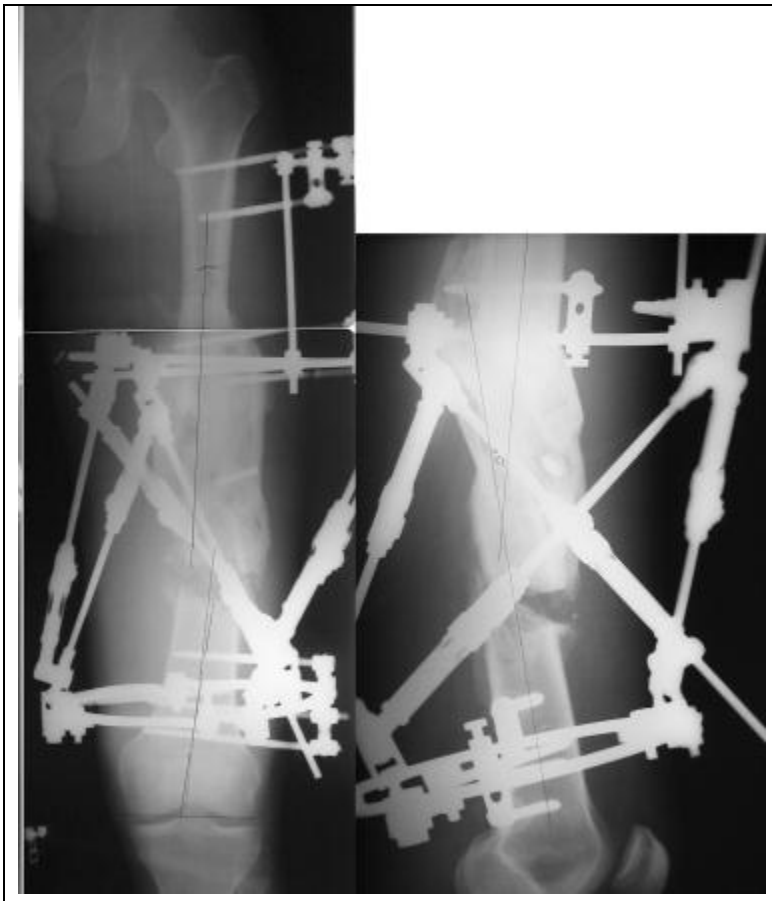
To achieve this, the following algorithm has been used. Locations of the intersection points between mechanical axis and femoral head and between mechanical axis and knee joint line on the AP view are known (chapter 2.8). At step 11, the angle of base fragment marker has been set, on the AP image, as 90º. It was done using the left mouse button. Mouse cursor was placed over the point where axis line and the line of the angle marker of base fragment intersect. Keeping left mouse button pressed, this intersection was placed exactly over the center of femoral head. Then, operating left mouse button, the cursor was placed over an end of line of the angle marker that "belongs" to the base fragment. With left mouse button pressed, the angle between line of the angle marker and axis line has been altered to achieve a state when this line connected center of femoral head with the apex of trochanter major.

In dialog box, in the field where value of angle marker for base fragment shows, the current value has been replaced with the required one (Fig. 66c,d): 90º. Position of the line of angle marker for mobile fragment changed automatically. By moving the centering line, line of the angle marker was manipulated into a state when it was positioned over a line that connects center of femoral head with the apex of trochanter (Fig. 66c,d). Angle of mobile fragment marker has been set to 88º. For this purpose, the axis line of mobile fragment marker has been set strictly in the middle of knee joint. Using left mouse button, mouse cursor was placed over an end of line of angle marker that "belongs" to mobile fragment. With left mouse button pressed, position of the line has been manipulated to change the angle between line of the angle marker and axis line. In the dialog box, in the field displaying the value of angle marker for mobile fragment, the current value was changed to required one: 88º. Position of the line of angle marker of mobile fragment in relation to axis line changed automatically. Line of the angle marker, using centering line as a handler, has been set on the distal joint line of femoral bone (Fig. 66c,d).

To determine the rate and the period of distraction two points were used - «*points of risk structures*». For this purpose in the dropout menu (the latter appears after right mouse button has been pressed within a roentgenogram field) the item "Vertical and horizontal lines visibility switch in/out". After this item had been selected with mouse cursor and the left mouse button pressed, green crossways consisting of one vertical and one horizontal lines intersecting at right angle to one another appeared next to roentgenograms (one intersection for one image). With left mouse button presses, the intersection was moved into the image area and set on a required point.

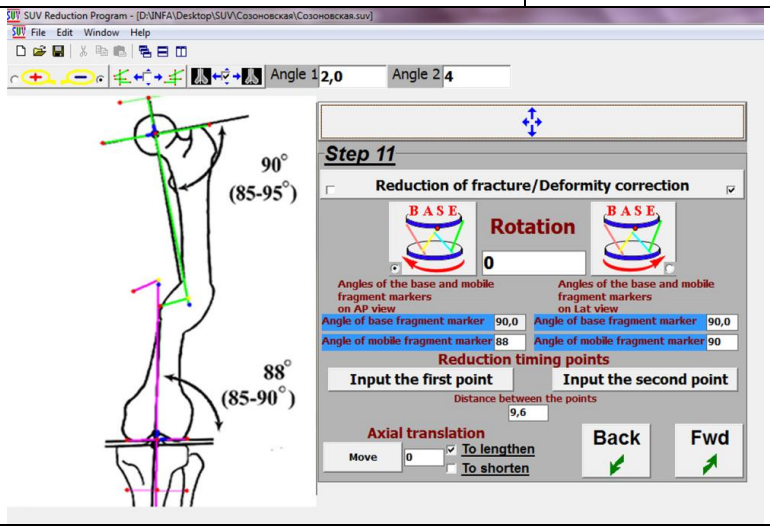
The first point has been set on the line of osteotomy, exactly where the mobile fragment in the process of its transport will cover the *longest distance* (Fig. 66e). After the first point has been placed in the chosen location on the AP and lateral roentgenograms, operator pressed the button «Input the first point". The second point has been set in the projection area of main vessels and nerves, on the spot, where the latter will get the maximum stretch during the deformity correction process (Fig. 66f). After the second point has been placed on its chosen location on the AP and lateral roentgenograms, the button «Input the second point" was pressed.

According to the software calculations, deformity correction has been performed and the correct position of mechanical axis of femur restored (Fig. 66g).

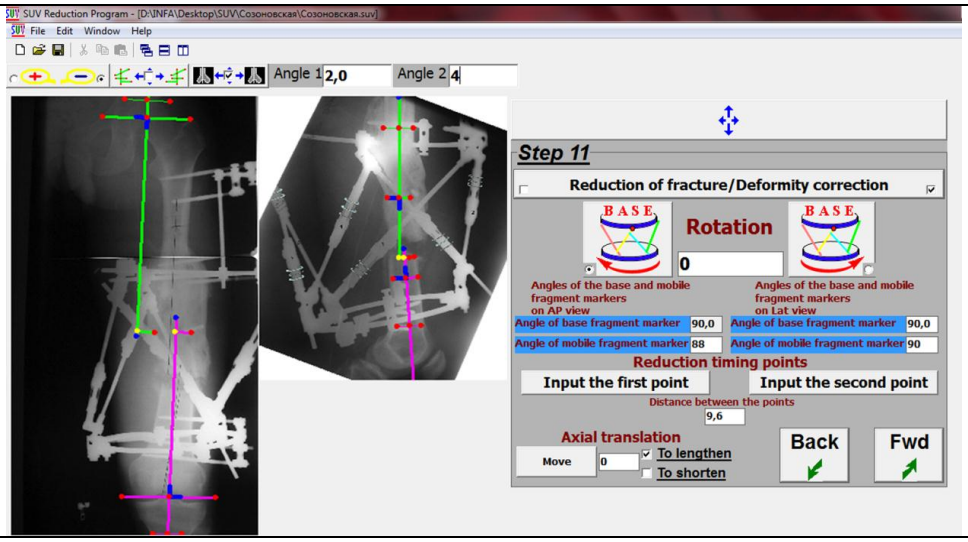


a

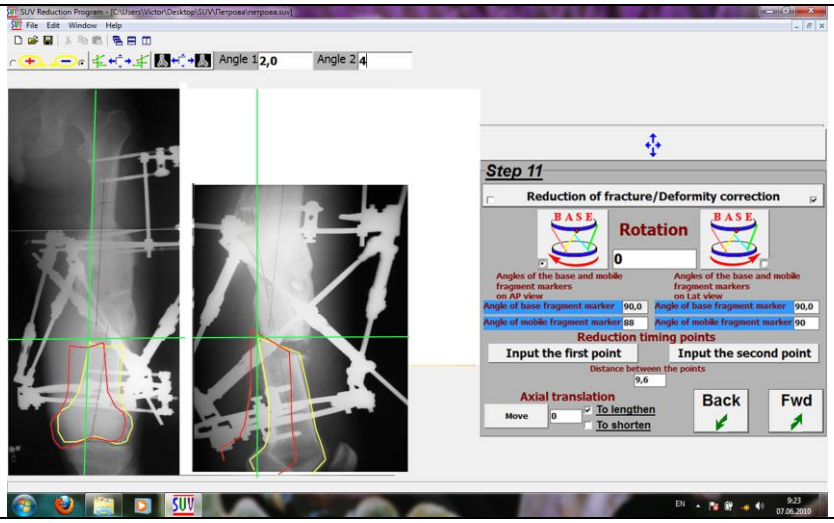
b


SUV Reduction Program - [D:\INFA\Desktop\SUV\Созоновская\Созоновская.suv]
File Edit Window Help
Angle 1 2,0
Angle 2 4
90°
(85-95°)
88°
(85-90°)
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 88
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90
Reduction timing points
Input the first point
Input the second point
Distance between the points
9,6
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

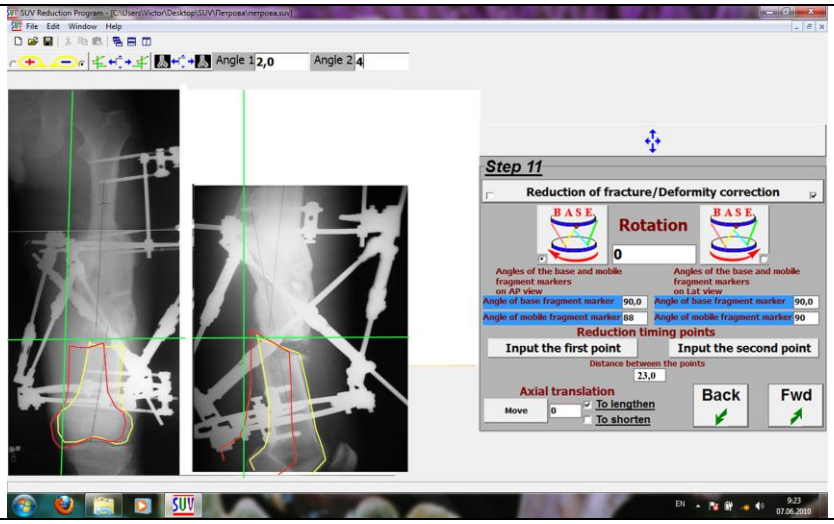
c


SUV Reduction Program - [D:\INFA\Desktop\SUV\Созоновская\Созоновская.suv]
File Edit Window Help
Angle 1 2,0
Angle 2 4
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 88
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90
Reduction timing points
Input the first point
Input the second point
Distance between the points
9,6
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

d


Angle 1 2,0
Angle 2 4
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 88
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90
Reduction timing points
Input the first point
Input the second point
Distance between the points
9,6
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

e


Angle 1 2,0
Angle 2 4
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 88
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90
Reduction timing points
Input the first point
Input the second point
Distance between the points
23,0
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

f

g

Fig. 66a-g. Photographs and roentgenograms of patient E.

6.3 Application of Ortho-SUV Frame in patients with metaphyseal deformity

Patient K. was hospitalized with the diagnosis: distal metaepiphysis nonunion in right tibia. Four-component, three-planar deformity of the right lower leg (Fig. 67a). Left femur fracture, consolidating in external fixation device.

As first stage, combined external fixation of right tibia bones had been performed, using Ortho-SUV frame (Fig. 67 b,c):

$$\underset{150}{\text{I,}\mathbf{9}\text{-3; I,}\mathbf{4}\text{-10; II,1,90}} \;\_\; \underset{150}{\text{IV,}\mathbf{10}\text{-4; V,2,90}} \;\_\; \text{Ortho-SUV} \;\_$$

$$\_\; \underset{150}{\text{VII(}\mathbf{8}\text{-2)8-2; VIII,}\mathbf{4}\text{-10}} \;\_\; \underset{\text{horseshoe-shaped support}}{\text{calc., }\mathbf{8}\text{-2; calc.,}\mathbf{4}\text{ -10; m/tars.,}\mathbf{V}\text{- m/tars.,I}}$$

While working with computer program, “deformity correction” mode was selected at step 11 (Fig. 67d). Using base fragment markers, anatomical axes of proximal fragment have been indicated on AP and lateral views. Due to the length of proximal fragment, it did not present any difficulties.

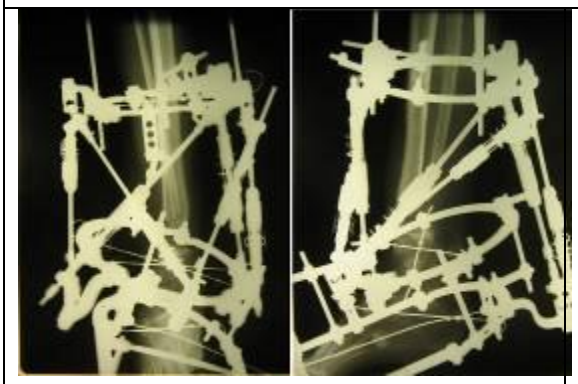
Due to the shortness of distal fragment - its length constituted just 35 мм –it was not possible to build its anatomical axis line. For this reason, in order to indicate its anatomical axis on AP and lateral views, the program capability for fragment markers to be set in accordance with epidiaphyseal (anatomical) angle has been used. Locations of intersection points between ankle joint lines and anatomical axes lines for AP and lateral views are known (chapter 2.8). For this reason, at step 11 the angle of mobile fragment marker has been set (Fig. 67d,e). For this, axis line of the mobile fragment marker has been set exactly over the center of the ankle joint. With left mouse button, mouse cursor was set over an end of the line of angle marker, "belonging" to mobile fragment. Keeping left mouse button pressed, line of the angle marker was manipulated to change the angle between the line of the angle marker and axis line. In dialog box, in the field where value of angle marker for mobile fragment shows, the current value has been replaced with the required one (Fig. 67d): 89º for AP view and 80º - for lateral view. After this, positioning of the line of angle marker of mobile fragment relatively to axis line changed automatically. After that, using center line as a handler, line of the angle marker has been set on the joint surface of tibia (Fig. 67e).

To determine the rate and the period of distraction, two points were used - «*points of risk structures*». For this purpose in the dropout menu (the latter appears after right mouse button is pressed within a roentgenogram field) the item "Vertical and horizontal lines visibility switch in/out" was selected. After left mouse-click, green crossways consisting of one vertical and one horizontal line intersecting at right angle to one another appeared next to roentgenograms (one intersection for one image). With left mouse button pressed, each intersection was moved to its respective image area and set into a required point.

The first point has been set along the osteotomy line, exactly where the mobile fragment in the process of its transport will cover the *longest distance* (Fig. 67f). After the first point has been placed in the chosen location on AP and lateral roentgenograms, operator pressed the button «Input the first point". The second point has been set in the projection area of great vessels and nerves, on the spot, where the latter will get the maximum stretch during the deformity correction process (Fig. 67g). After the second point had been placed on its chosen location on both AP and lateral roentgenograms, the button «Input the second point" was pressed.

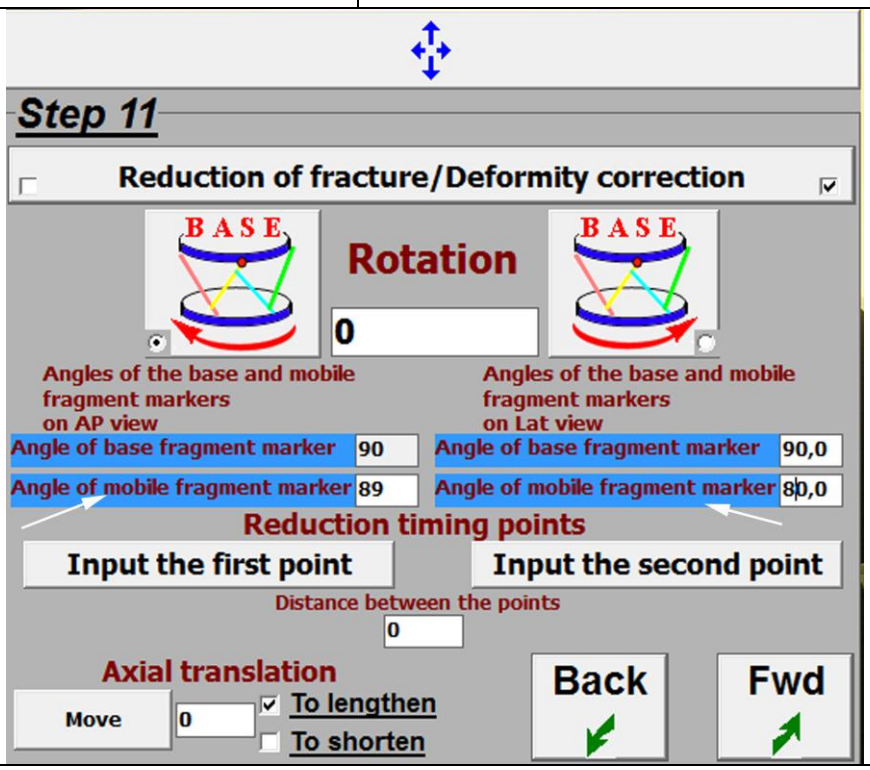
At step 12 the rate of deformity correction - 1 мм per day – was set and button "Calculate" pressed. Following this, program calculated the recommended quantity of days required for correction of the deformity. When operator pressed «Show», at the lower right field of the display a table appeared showing the values of daily length change for every strut (Fig. 67h). This table was printed out and given to the patient. Deformity correction has been performed in accordance with program calculations (Fig. 67i). Struts of the Ortho-SUV device were replaced by hinges of an Ilizarov's frame (Fig. 67j). Next stage involved bone transfer at nonunion site by autogenous bone graft taken from iliac crest, followed by corticotomy and osteoclasy at level II to correct limb length discrepancy (Fig. 67k).

a

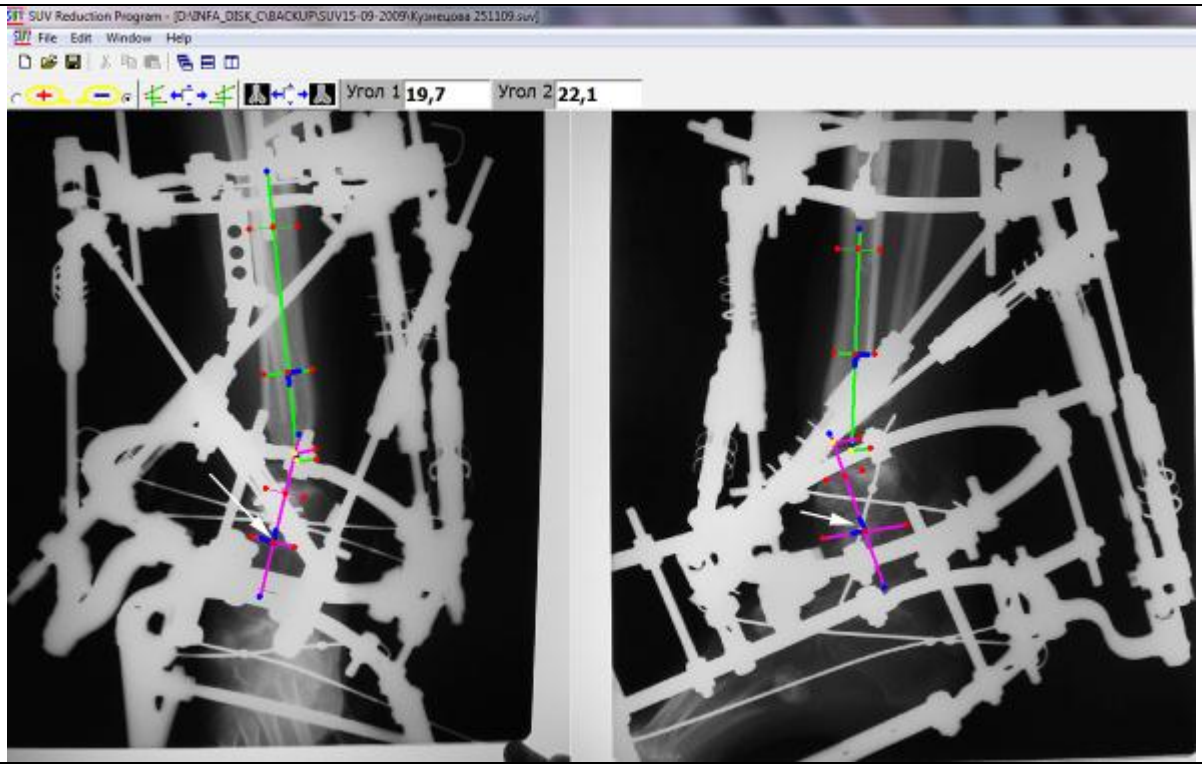


b

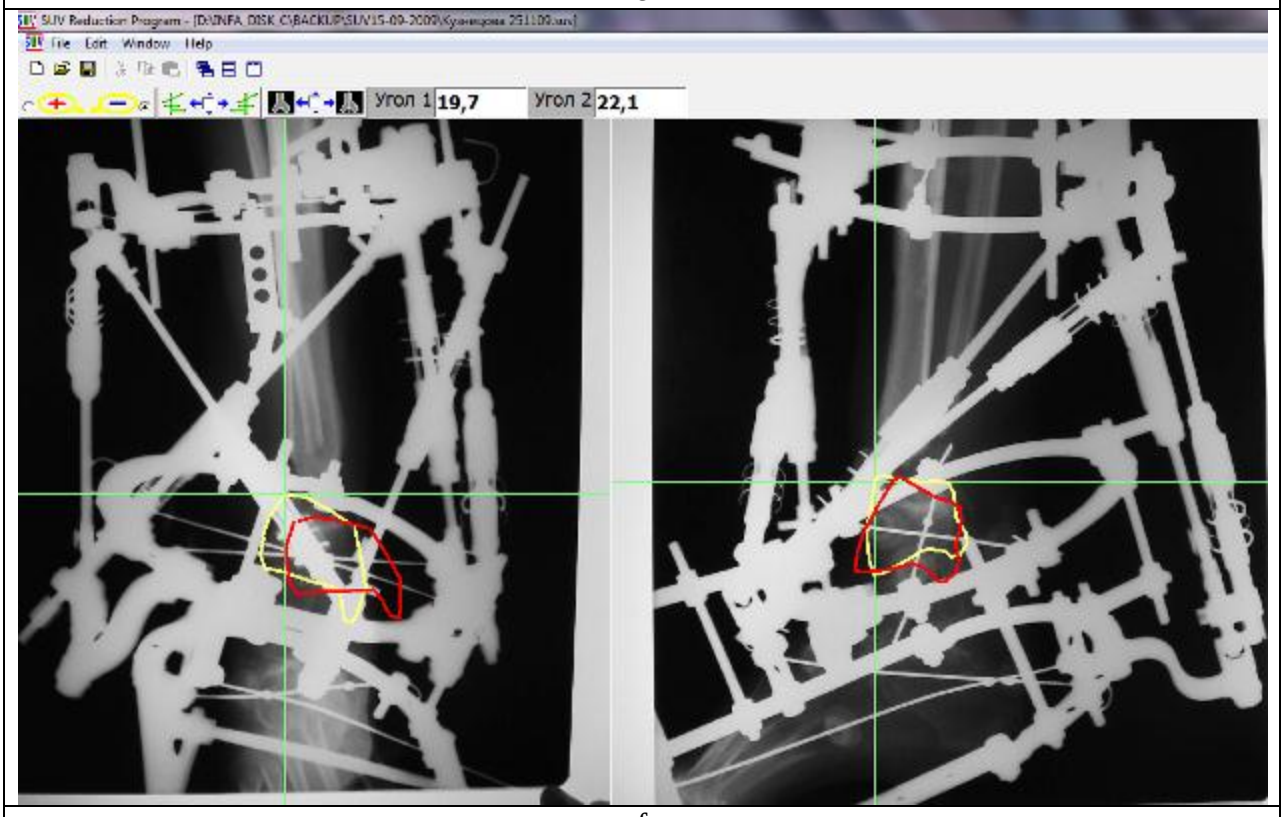
c


Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angle of base fragment marker 90
Angle of mobile fragment marker 89
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90,0
Angle of mobile fragment marker 80,0
Reduction timing points
Input the first point
Input the second point
Distance between the points
0
Axial translation
Move
0
To lengthen
To shorten
Back
Fwd

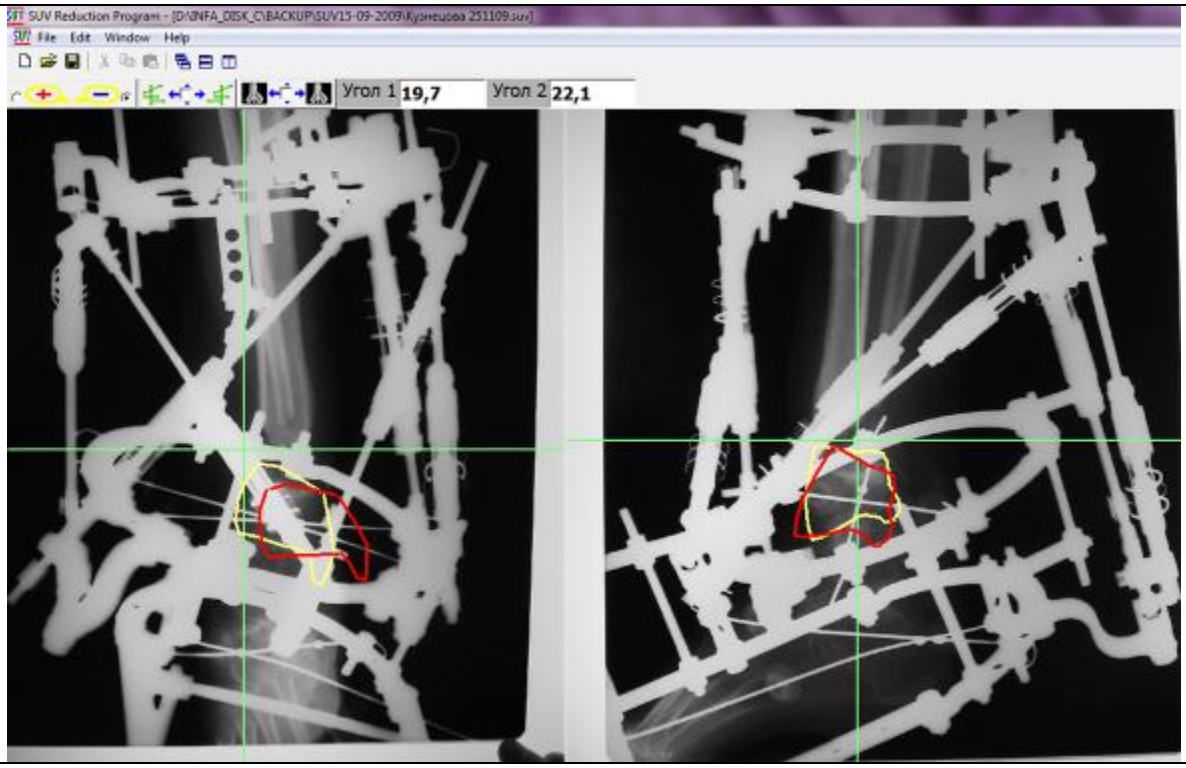
d


SUV Reduction Program
File Edit Window Help
Угол 1 19,7
Угол 2 22,1

e


SUV Reduction Program
File Edit Window Help
Угол 1 19,7
Угол 2 22,1

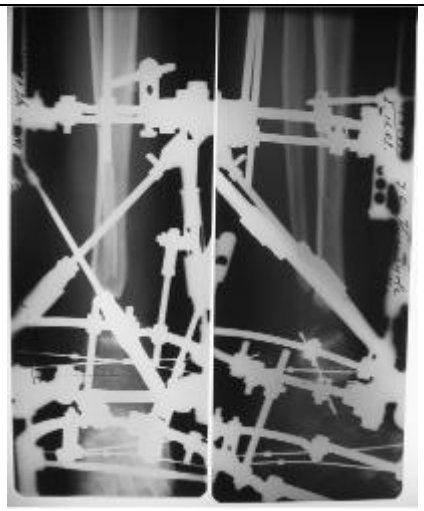
f


SUV Reduction Program - [D:\INFA_DISK_C\BACKUP\SUV15-09-2009\Кузнецова 251109.suv]
File Edit Window Help
Угол 1 19,7
Угол 2 22,1

g

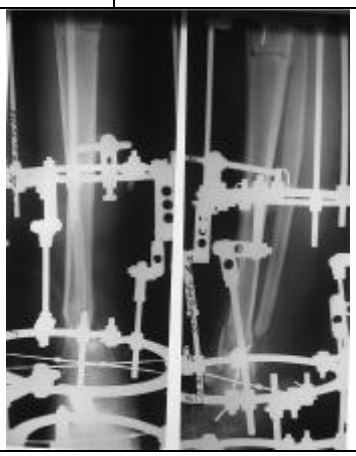
SUV Reduction Program - [D:\INFA_DISK_C\BACKUP\SUV15-09-2009\Кузнецова 251109.suv]
File Edit Window Help
Угол 1 19,7
Угол 2 22,1
Step 12
Strut length change
Rate of correction 1 mm/day
Calculate
Recommended number of days 8
Back
Show
Print
Clean
Name, age: Egorov I.M.
Diagnosis: Non-union
Histoty of physical: 1644
Date: 15022010
Day Str1 Str2 Str3 Str4 Str5 Str6
Day: 0 131,00 144,00 174,00 144,00 144,00 149,00
08:00 +1 +2 +2 +3 +2 +1
12:00 +1 +2 +3 +2 +3 +2
16:00 +2 +2 +2 +3 +2 +1
20:00 +1 +2 +3 +3 +2 +2
Day: 1 132,25 146,00 176,50 146,75 146,25 150,50

h



i

j



k

Fig. 67a-k. Photographs and photoroentgenograms of patient K. prior to, during and after the treatment: d – Arrows indicate the dialog box fields where values of epimetaphyseal angles were entered; e – Arrows indicate lines of angle markers of mobile fragments, set on the joint surface of tibia

6.4 Application of Ortho-SUB Frame for deformity correction of foot

Patient Z. (Fig. 68a) has been hospitalized with the diagnosis: complex deformity of right foot with 5 cm shortening.

At first stage, V-shaped foot osteotomy (calcaneum osteotomy and osteotomy at the level of tarsus bone) followed by combined external fixation of right foot bones were performed, using two Ortho-SUV Frames (Fig. 68b):

$$\frac{\quad}{120} \; \_ \; \frac{\text{VII } 11{,}110;\ \text{VIII},\mathbf{4}\text{-}10;\ \text{VIII},\mathbf{8}\text{-}2(8\text{-}2)}{120} \; \text{--Ortho-SUV --} \; \frac{\text{calc}.\mathbf{4}\text{-}10;\ \text{calc}.\mathbf{8}\text{-}2}{2/3\ 110} \; \text{–0–}$$

$$\text{–0–} \; \frac{\text{tars}.\mathbf{4}\text{-}10;\ \text{tars}.\mathbf{8}\text{-}2}{120} \; \text{-- Ortho-SUV --} \; \frac{\text{m/tars}.\mathbf{I}\text{- m/tars.II; m/tars}.\mathbf{V}\text{- m/tars.III}}{120} \; \text{--} \; \frac{\quad}{120}$$

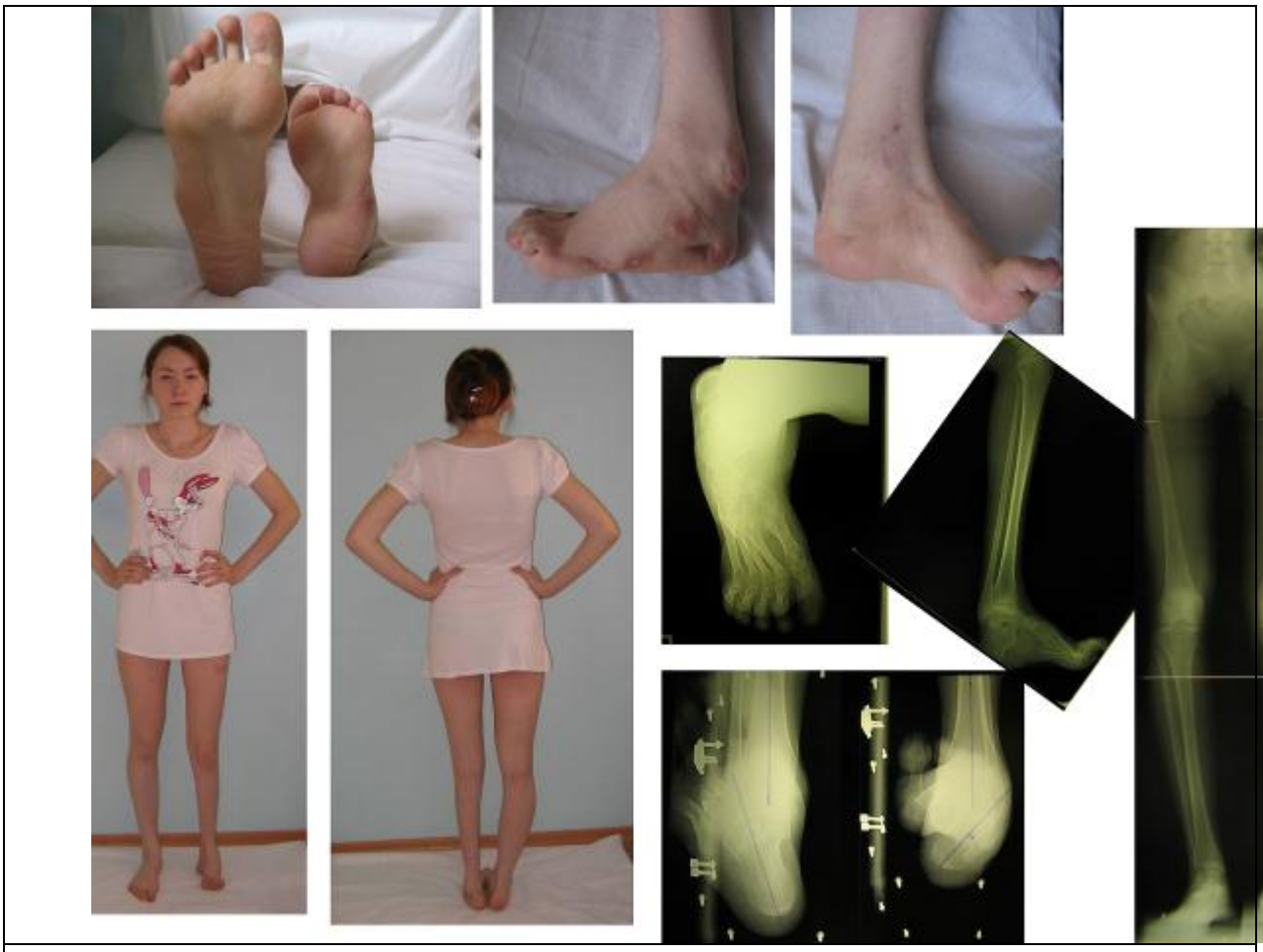
To facilitate fixation of struts proximal and distal supports (without transosseous elements) were used in the assemblage process.

Program calculations were performed separately for every frame (that is, for every osteotomy level). One document was created to perform calculations for deformity correction of hindfoot relatively to the lower leg (Fig. 68c). Calculations for deformity correction of the midfoot relatively

to the hindfoot were conducted in the second document (Fig. 68d). Reference lines discussed in chapter 2.14 were used. Proceeding from these calculations, deformity correction has been carried out (Fig. 68e). Upon completion of deformity correction, module transformation using external fixation device was performed. Struts of the Ortho-SUB frame were replaced with hinges of an Ilizarov's frame (Fig. 68f). Final frame assembly:

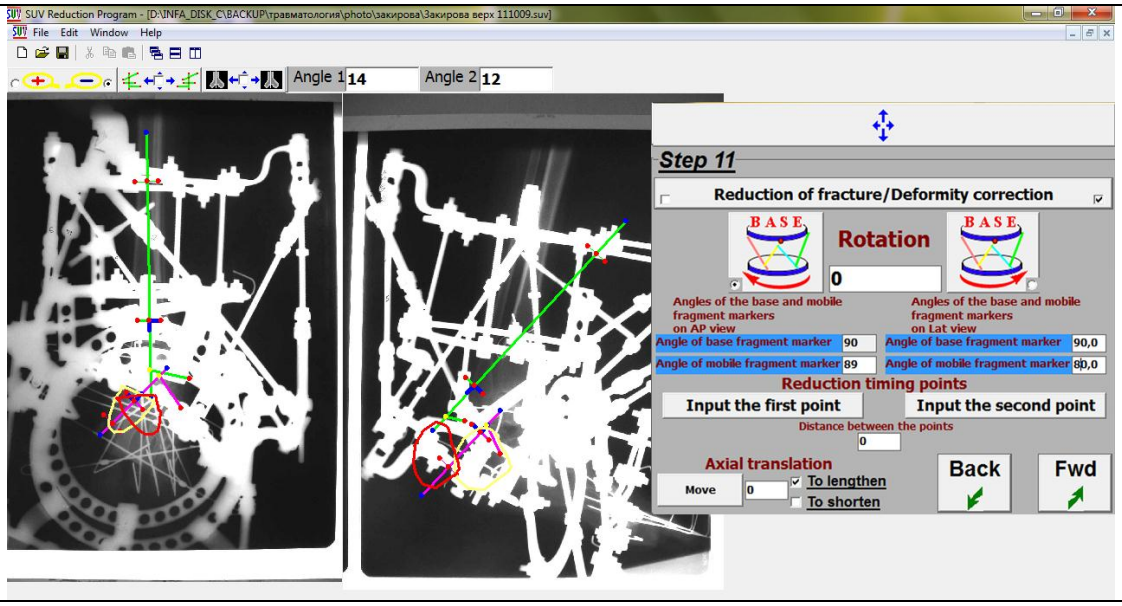
$$\underset{120}{\underline{\text{VII } 11{,}110;\ \text{VIII},\mathbf{4}\text{-}10;\ \text{VIII},\mathbf{8}\text{-}2(8\text{-}2)}}\ \text{--0--}\ \underset{2/3\ 110}{\underline{\text{calc}.\mathbf{4}\text{-}10;\ \text{calc}.\mathbf{8}\text{-}2}}\ \text{–0–}$$

$$\text{–0–}\ \underset{120}{\underline{\text{tars}.\mathbf{4}\text{-}10;\ \text{tars}.\mathbf{8}\text{-}2}}\ \text{--0--}\ \underset{120}{\underline{\text{m/tars}.\mathbf{I}\text{- m/tars.II; m/tars}.\mathbf{V}\text{- m/tars.III}}}$$

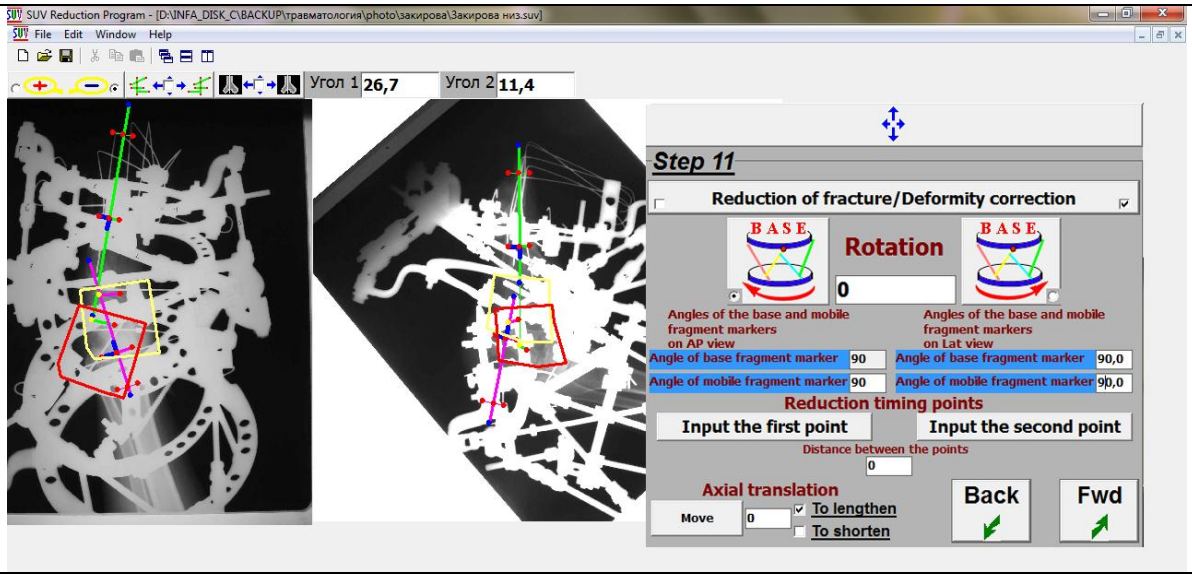


a

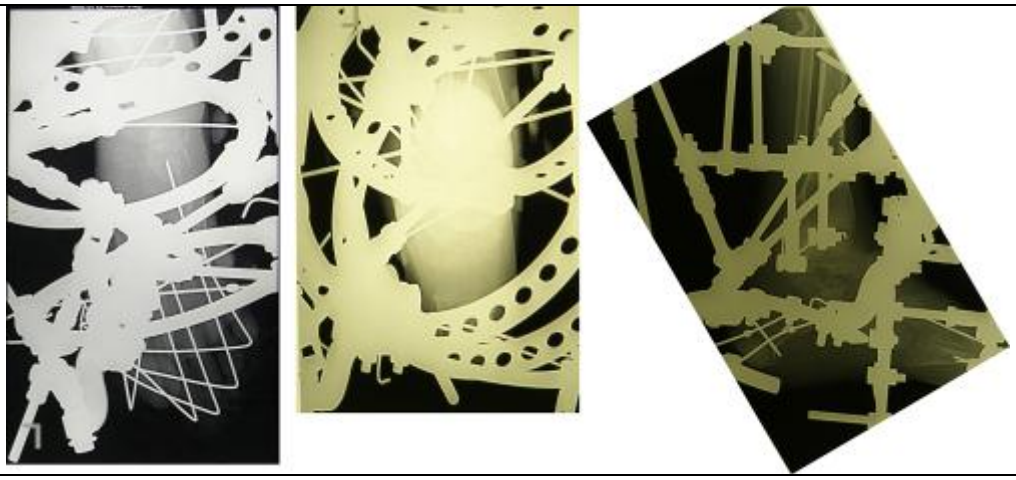
b


SUV Reduction Program - [D:\INFA_DISK_C\BACKUP\травматология\photo\закирова\Закирова верх 111009.suv]
File Edit Window Help
Angle 1 14
Angle 2 12
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90
Angle of mobile fragment marker 89
Angle of base fragment marker 90,0
Angle of mobile fragment marker 80,0
Reduction timing points
Input the first point
Input the second point
Distance between the points
0
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

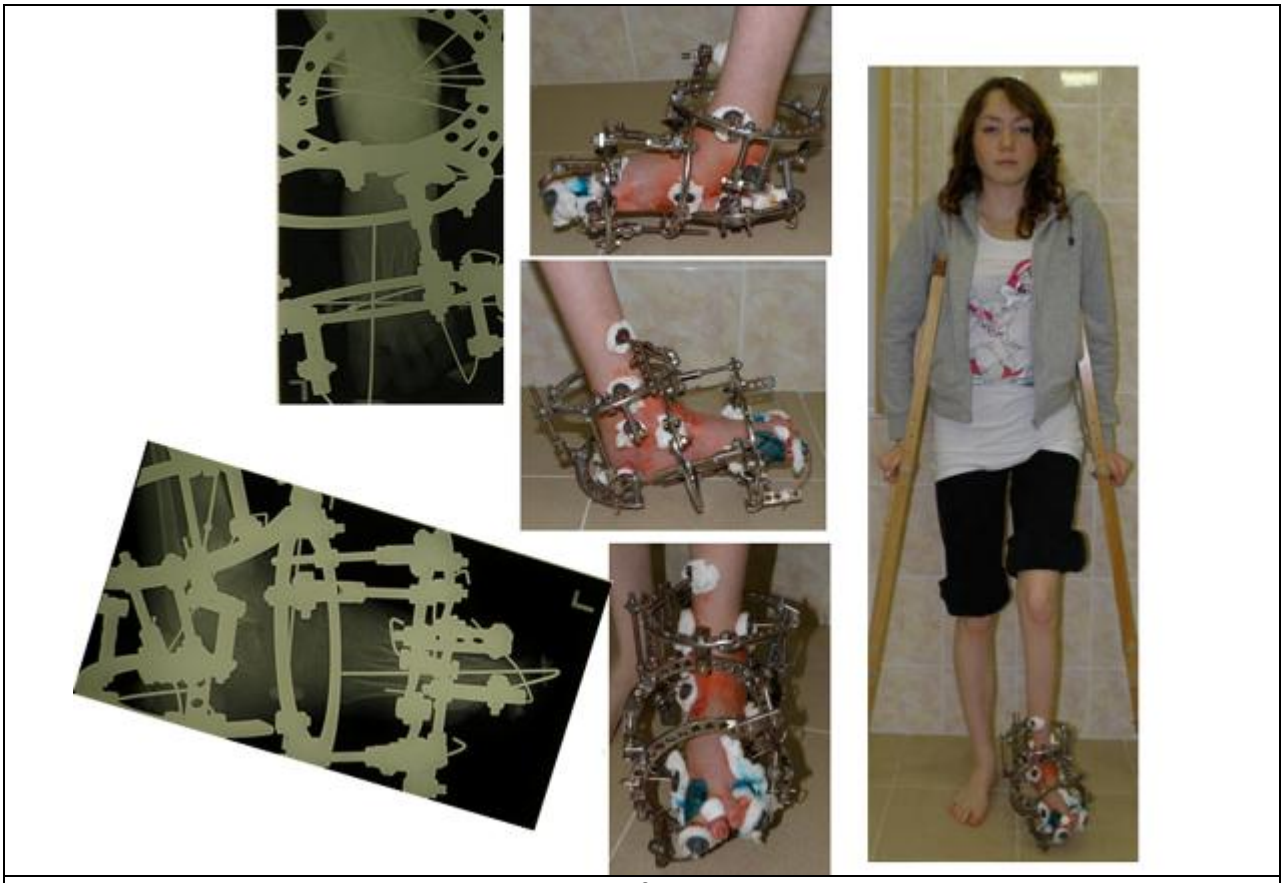
c


SUV Reduction Program - [D:\INFA_DISK_C\BACKUP\травматология\photo\закирова\Закирова низ.suv]
File Edit Window Help
Угол 1 26,7
Угол 2 11,4
Step 11
Reduction of fracture/Deformity correction
BASE
Rotation
BASE
0
Angles of the base and mobile fragment markers on AP view
Angles of the base and mobile fragment markers on Lat view
Angle of base fragment marker 90
Angle of mobile fragment marker 90
Angle of base fragment marker 90,0
Angle of mobile fragment marker 90,0
Reduction timing points
Input the first point
Input the second point
Distance between the points
0
Axial translation
Move 0
To lengthen
To shorten
Back
Fwd

d



e



f

Fig. 68a-f. Photographs and photoroentgenograms of patient Z. before and during the treatment

6.5 Application of Ortho-SUV Frame for the treatment of knee joint stiffness

Patient P. was hospitalized with the diagnosis: consolidated fracture of left femur, persistent flexion stiffness of left knee joint.

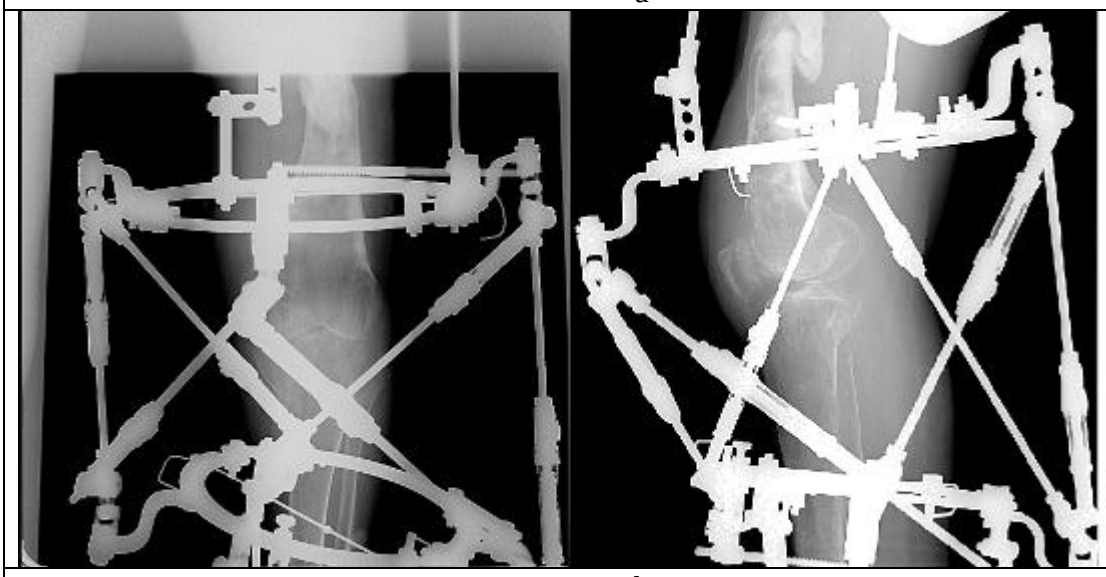
Upon admission, motion range in left knee joint amounted to 15/0/0 (Fig. 69a). Arthrolysis, tenolysis, myolysis of left knee joint had been performed followed by Ortho-SUV frame application (Fig. 69b):

III,10,90; IV,8,90 __ VII,**3**-9; VII,8,90 _ Ortho-SUV _
¼ 200 180

-- III,**4**-10; IV,1,80 __ VIII(**8**-2)8-2; VIII, **4**-10
150 150

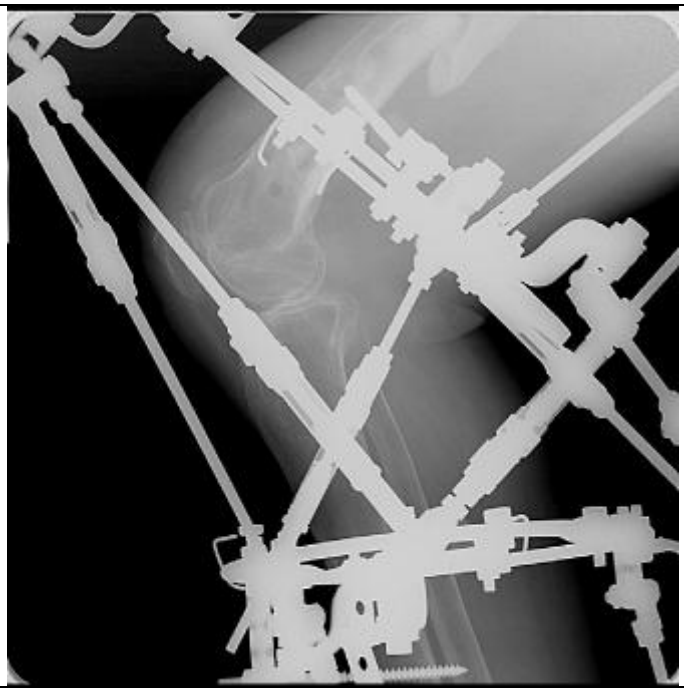
While performing program calculations, to identify the motion curve of the joint end of tibia relatively to femur, the scheme 2.15.53 was applied. Proceeding from these calculations, knee joint flexion up to 90 degrees was completed (Fig. 69c,d) in 12 days. The circle "90 degree flexion – 0 degree extension" was then performed, using Ortho-SUV frame, 10 times during the course of following 5 days. Then struts of the Ortho-SUV device were removed and the patient performed active motions in knee joint (Fig. 69e). After that the external fixation device was removed. In follow-up period the motion range in knee joint remains 90/0/0 (Fig. 69f).

a



b

c



d

e

f

Рис. 69a-f. Photographs and photoroentgenograms of patient P. before, during, and after the treatment. Note the correct interrelations in the knee joint during treatment

7 Tips and tricks at using Ortho-SUV Frame

Table 1 shows possible specific difficulties that can occur while working with Ortho-SUV frame as well as their prophylaxis and elimination.

As the Table shows, almost all possible complications occur in the result of incorrect use of the hardware and (or) software. Though, if you have not managed to find the cause and you experience difficulties in working with the program save the program file and e-mail it together with the patient's X-rays to orthosuv@gmail.com. In the cover letter please explain in detail the nature of the problem occurred. That is why do not forget to save the file after each step of the program. You can find all the information concerning the training programs on the Ortho-SUV software at http://rniito.org/solomin.

Table 1
Complications occurring with use of Ortho-SUV Frame

#	Complications	Main causes	Prophylaxis	Elimination
1	During the external fixation frame assembly it is difficult to connect the struts with each other	The initial struts arrangement differs from that on Fig. 5b	Arrange the struts as it is shown on Fig. 5b	Before the external fixation frame assembly, arrange the struts the way as it is shown on Fig. 5b.
2	Due to the short distance between the basic supports it is difficult or impossible to arrange the struts	The distance between the supports is less that 120-150 mm	1. The distance between the supports, if possible, must be not less than 150 mm. 2. Using Z-shaped plates to fix the struts (Fig. 12b) 3. Using stabilizing supports to fix the struts (Fig. 12c)	1. Partial reassembly of the external fixation frame 2. Fixation of struts using Z-shaped plates (Fig. 12b) 3. Fixation of some struts to the stabilizing supports (Fig. 12c)
3	When trying to proceed to Step 2, the program shows a dialog box "The angle between the strut and support is less than the valid norm of 20°" or "Data error"	1. Incorrectly entered values of the struts lengths or sides of the triangles: wrong length or it is entered in cm. You just may have confused the struts' numbers and (or) the sides of the triangles. 2. The struts are located at an angle of 20° to the support, i.e. close to the horizontal plane or even there is a negative angle of the struts' assembling	1. Entering the correct values of the struts' lengths and the sides of the angles in mm. 2. The struts must be located at an angle of over 20° to the support	1. Entering correct data in the program 2. Partial reassembly of the external fixation frame, which requires taking an additional X-ray
4	When loading the anterior X-ray (Step 2), it does not appear in the program window	It is the way the program works: both X-rays appear after loading the lateral X-ray	-	-
5	When reloading the file (with which all the program steps have been proceeded), on Step 3 the previously loaded X-rays are not visible	It is the way the program works: you will be able to work with X-rays on all the following steps of the program	-	-
6	It appears to be impossible to	1. The X-rays are made on narrow film and do	1. The X-ray field must include all struts and	X-rays must be retaken

	define the number of struts and joints necessary for proceeding to the next step on the X-ray (Steps 6 and 7); it is difficult to define the numbers of the struts and joints	not include all struts and joints. 2. When taking X-rays the struts' markers were not used (Fig. 5d).	joints. 2. Before taking the X-rays, the struts' markers must be put on the struts (Fig. 5d).	
7	In spite of all struts and joints have been marked while taking Step 6 or 7, the program does not allow you to proceed to the next Step	You have forgotten to enter the focal distance and (or) the center of the beam	Entering all the data required in this window	Enter the focal distance and the beam center
8	Having completed Step 7, the program shows red lines that do not coincide with the projections of the struts: starting from non-coincidence of one of the lines up to the total displacement of all lines relating to the external fixation frame. The extreme case is when the red lines are beyond the visible field.	1. Incorrect assembly of the external fixation frame: first of all not following the "red screws rule" and "watch rule" (Section 3.1). 2. Incorrectly entered lengths of the struts and triangles' sides or entering the values in cm (Step 1) 3. Incorrect scaling (Step 4 and 5): the length of the known section is less than 80 mm and (or) the length of the known section is entered in cm 4. Incorrectly entered focal distance (Step 6 and 7) or the focal distance is entered in cm 5. Incorrectly marked numbers of the struts and (or) joints, i.e. not corresponding to the assembly of the external fixation frame (Steps 6 and 7). 6. Thus, coincidence of the red lines with the struts' projections depends on the exact and correct completion of Steps 1-7	1. Correct assembly of the external fixation frame 2. Exact entered values of the lengths of the struts and sides of the triangles in mm. 3. Exact value of the known section length entered in mm. 4. Exact value of the focal distance entered in mm. 5. Marking the struts' numbers and (or) joints according to the assembly of the external fixation frame. To do it, use the struts' markers when taking an X-ray (Fig. 5d). 6. Control whether the values have been entered correctly when completing Steps 1-7. If the anterior and lateral X-rays have been taken not in the orthogonal projections, on Step 6 and 7 maximally possible numbers of struts and joints must be marked.	1. Partial reassembly of the external fixation frame, which requires taking an additional X-ray. 2. Exact lengths of the struts and sides of the triangles entered in mm. 3. Exact length of the known section entered in mm. 4. Exact focal distance entered in mm. 5. Entering the numbers of the struts and joints according to the assembly of the external fixation frame. 6. Thorough control over the correct data entered during Steps 1-7. Return to Step 6 and 7 and mark maximally possible numbers of the struts and joints.

9	When trying to proceed to Step 11, the program shows a dialog window "Specify the values of the mid-diaphyseal lines"	1. Different lengths of the bone contours (Step 9) of the mobile bone fragment on the anterior and lateral views 2. The anatomical axes (Step 10) of the mobile bone fragment on the anterior and (or) lateral views do not sufficiently exceed the upper or lower margins of the bone contour. 3. When drawing the bone contours or constructing the anatomical axes, there are accidentally marks drawn (points, lines) beyond the bone contour or anatomical axis.	1. The lengths of the bone contours on the anterior and lateral views are to be equal. 2. Anatomical axes must exceed the margins of the bone contours by 20-30 mm. 3. Before moving the X-rays, their minimizing or magnification click the move X-ray images button (Fig. 26).	1. Erase the bone contours and draw them once again but of equal length. 2. If it is impossible to draw the anatomical axis above the distal end of the bone contour (short X-ray) return to Step 9, erase the bone contour and draw the new one, which must be shorter than the initial bone contour. 3. Erase accidental signs from the X-ray fields.
10	When trying to change the position of the red bone contour by moving the distal fragment marker (Step 11), the form of the bone contour is changing – it starts "rotating"	he program is in the "Fracture anatomical reduction" mode	Before moving the bone contour take a look, which of the program mode is chosen: "Fracture anatomical reduction" or "Deformity correction".	Check the "Deformity correction" check-box. If the "Deformity correction" check-box is checked, check the "Fracture reduction" check-box and then return back to the "Deformity correction" mode.
11	Clicking the "Calculate" button to calculate the number of days for the deformity correction or fracture reduction (Step 12), the program shows the dialog window "Switch off the move fragment markers button mode and click the superposition pointer"	In the program options "Bone fragments markers movement" and (or) "move X-ray images" are switched in (Fig. 26). Besides, to make the program "understand" that you intend to move the fragment in three views, before proceeding to Step 12, click on the connection point markers (Fig. 42-5) on the proximal and distal bone fragments on the lateral view.	Before proceeding to Step 12 the "Bone fragments markers movement" and "move X-ray images" options must be unchecked (Fig. 26). Besides, you should click on the connection points' markers (Fig. 42-5) on the proximal and distal bone fragments on the lateral view.	Switch off the "Bone fragments markers movement" and "move X-ray images" options (Fig. 26). Click on the connection points markers (Fig. 42-5) on the proximal and distal bone fragments on the lateral view.
12	After clicking the "Calculate" button	To calculate the number of days required for the	Do not forget to locate both structure at risk	Return to Step 11 and set the structure at risk

	to calculate the number of days required for the deformity correction or fracture reduction, (Step 12), the program gives obviously incorrect result: for example, shows that for 5 mm distraction 17 days are required.	deformity correction or fracture anatomical reduction the program always use the structure at risk points (Fig. 58 and 59). If you have forgotten to set them, the program considered the default structure of risk points, which cannot be applicable to the individual case calculated.	points exactly (Fig. 58 and 59).	points exactly (Fig. 58 and 59).
13	During the deformity correction the struts began to press on the soft tissues or bear against the outstanding ends of the half-pins.	Incorrect initial assembly of the external fixation frame	During the surgery planning it is to be considered in what direction the distal main support and struts are moved	Partial reassembly of the external fixation frame
14	In case of maximal distraction in the "Deformity correction" mode the threaded rod (Fig. 6) has completely got out of the strut length changing unit (Fig. 8): disconnection of the unit and threaded rod has occurred, causing the external fixation frame destabilizing.	There is no thread on one of the ends of the threaded rods packed in the Ortho-SUV Frame set, which excludes disconnection of the strut length changing unit and the threaded rod. If this kind of complication has occurred, the rods being used in the external fixation frame assembly do not belong to the Ortho-SUV set.	1. Use only the threaded rods packed in the Ortho-SUV set. 2. The threaded bush of the strut length changing unit (Fig. 8) has a slot. It can be used to control the position of the peripheral end of the threaded rod.	Partial reassembly of the external fixation frame: replacing the threaded rod by a longer size
15	On the control X-ray there is no exact anatomical shown (deformity correction): the location of the distal fragment does not fully correlate with the location of the red bone contour (Step 11)	1. It is this location of the distal fragment that has been set by the user on Step 11: look at the location of the red bone contour relating to the main (proximal) fragment with maximal magnifying 2. Unstable fixation of the bone fragments by proximal and (or) distal external fixation unit: as	1. The yellow bone contour (Step 9) must exactly coincide with the contours of the mobile bone fragment. When completing the planning of the deformity correction or fracture reduction (Step 11), you should control the location of the red bone contour relating to the proximal fragment,	1. Additional program calculation and elimination of the residual displacement 2. Reassembly of the external fixation frame (stabilizing the supports), repeated calculation in the program and elimination of the residual displacement 3. Taking control X-rays

		a rule the displacement of the bone fragment relating to the support occurs due to the deformity of the transosseous elements 3. Projections of X-rays taken before and after the deformity correction do not coincide	using maximal magnification. 2. Fixation of the proximal and distal bone fragments must be stable and excluding the possibility of the fragments displacement relating to the appropriate supports. 3. Take X-rays in the same views	in views different from the initial ones enabled you to detect the additional displacement of the fragments. You should make an additional calculation in the program and eliminate the residual displacement.
16	The control X-ray shows that the fragments have interconnected, which prevents to perform the reduction or deformity correction. That is why the further change of the struts' length will only result in the deformity of the bone fragments and the whole external fixation frame.	It should be considered that the program calculates the integral trajectory on the bone fragment reduction, i.e. according to the shortest distance. That is why if there is a axial displacement of the bone fragments (the proximal end of the distal fragment is located higher than the distal end of the proximal fragment) and if you try to eliminate the translation, the fragments are to become interconnected inevitably.	If the proximal end of the distal fragment is higher than the distal end of the proximal fragments, the deformity correction (fracture reduction) must be performed in two stages. On the first stage distraction is made to provide 3-4 mm diastasis between the bone fragments (program calculation planned for distraction). On the second stage the residual displacement is eliminated (the second calculation in the program).	
17	After the work is complete the program does not shut down	You have removed the hasp-key before shutting down the program	First shut down the program and only after that remove the hasp-key	Insert the hasp-key in to the USB-port and after that shut down the program

8. Instead of the conclusion

8.1. Legalization

Ortho-SUV Frame is patented and certified. All rights are reserved. Copyright, Patent, and License infringement will be punishable by the fullest extent of the Russian Federation laws.

For any questions concerning copyright and license agreement registration apply to:

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8.2. Ortho-SUV Frame training courses and workshops

Electronic version of Ortho-SUV Frame user manual is placed on the site http://www.rniito.org/download/ortho-suv-manual-eng.pdf.

Training courses and associated workshops concerning the Ortho-SUV Frame take place at the Vreden Russian Research Institute of Traumatology and Orthopedics:

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http://rniito.org/solomin

Three variants of training courses are offered for your choice:

1. A nine-day base course "Basic principles of deformity correction by Ilizarov device and Ortho-SUV Frame" (details: http://www.rniito.org/download/ortho-suv-course-9-eng.pdf).
2. A nine-day base course "Basic principles of deformity correction by Ortho-SUV Frame and Ilizarov device" (details: http://www.rniito.org/download/ortho-suv-Iliz-course-9-engl.pdf)
3. A four-day intensive course «Bases of deformity correction by Ortho-SUV Frame» (details: http://www.rniito.org/download/ortho-suv-course-4-eng.pdf).

It is possible to arrange Ortho-SUV training courses in your hospital (details: http://www.rniito.org/download/ortho-suv-course-out-eng.pdf).

All questions arisen send to: solomin.leonid@gmail.com, orthosuv@gmail.com

To the attention of scientists and orthopedic surgeons

We invite you to take part in scientific and practical work, associated with the Ortho-SUV Frame application and improvement. Further information can be send to Prof. Leonid N. Solomin: Vreden Russian Research Institute of Traumatology and Orthopedics; solomin.leonid@gmail.com, http://rniito.org/solomin

8.2. Where to acquire

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